FIFTIETH ANNUAL REPORT

OF THE

Agricultural Experiment Station

OF THE

UNIVERSITY OF KENTUCKY

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PART II

Bulletins 368-377
Circulars 46-48

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LEXINGTON

1937

FIFTIETH ANNUAL REPORT

OF THE

Kentucky Agricultural Experiment Station

FOR THE YEAR 1937

PART II

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Kentucky
Agricultural Experiment Station

University of Kentucky

ORGANIZATION OF THE LOUISVILLE WHOLESALE FRUIT AND VEGETABLE MARKET

BULLETIN NO. 368

Lexington, Ky.

March, 1937

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BULLETIN NO. 368

Organization of the Louisville Wholesale Fruit and Vegetable Market

By H. B. PRICE, C. D. PHILLIPS and S. E. WRATHER

At the request of the Jefferson County Farm Bureau, a study of the Louisville fruit and vegetable market was started in July, 1935, to get information regarding the organization and operation of the market. Information was obtained by personal interviews with growers who patronize the market, inter-city truckers and railroads hauling produce into and out of the market, wholesale dealers, and other agencies. A preliminary study was started in 1935 in expectation of completion in 1936, but a severe local drouth in 1936 created such abnormal relationships between local production and shipments of fruits and vegetables both into and out of the market that only a preliminary report can be made at this time.*

City produce markets have been under considerable pressure in recent years to increase facilities for handling and to improve the organization for marketing fruits and vegetables. Increased consumption of these products has made it imperative to improve and expand facilities for handling them. Greater dispatch and mobility in transportation has required development of those functions in marketing that facilitate intra-city and inter-state commerce. City markets that formerly functioned to supply the local population with fruits and vegetables are now often expected to take on the characteristics of a well-developed marketing system supplying a fairly large territory. This is particularly true where there is local advantage in producing fruits and vegetables.

Some of the important characteristics of city produce markets that meet the requirements of present-day needs are: first, ample facilities, well located and equipped to handle the physical supply with dispatch and at a reasonable cost; second, a market organiza-

*Acknowledgment is made of the cooperation of S. W. Anderson, County Agent in Jefferson County, the Department of Horticulture, University of Kentucky, officers of the Jefferson County Farm Bureau, engineers in the Engineering Department of the City of Louisville, officials of the Gardeners' and Farmers' Market, wholesale dealers, inter-city truckers and fruit and vegetable growers too numerous to mention.

tion that promotes exchange of commodities; and third, an adequate source of information to facilitate exchange, including systems of price quotations, market news, grading and inspection of products, standardization of packs and packages and other functions designed to provide a satisfactory basis for buying and selling.

This study was intended to test the Louisville market by the present-day requirements in marketing locally-grown fruits and vegetables. Since the time and resources at the disposal of the authors in 1935 and the unfavorable season in 1936 did not permit a full and thorogoing study of all aspects of the market organization, an evaluation of the efficiency of the market as a whole, cannot be made until there is opportunity for further research. However, inquiry has been made into certain important aspects of the market, the findings of which are here presented.

IMPORTANCE OF LOUISVILLE FRUIT AND VEGETABLE MARKET

Louisville is an important wholesale market for fruits and vegetables and, as such, it not only supplements locally-grown fruits and vegetables with produce shipped in from distant producing areas, but it also serves as the only source of supply of these products for a rather large area in Central Kentucky and Southern Indiana.

According to the best information available, fruits and vegetables amounting to between 11 and 12 thousand carloads are handled on the market yearly. Railroad receipts during 1936 amounted to 5,256 carloads; the equivalent of more than 3,000 carloads were received by motor truck, while approximately 3,000 carloads of locally-grown produce were handled on the market.

Fruits and vegetables are shipped into Louisville from every important producing area in this country as well as from some foreign countries, as is indicated by the accompanying chart (Figure 1) showing state-of-origin of car-lot unloads of fruits and vegetables during 1936 in Louisville.

The volume of these products has steadily increased in recent years. Railroad receipts in 1934 amounted to 4,174 carloads. This increased to 4,475 carloads in 1935 and to 5,256 in 1936. Data on receipts shipped in by motor truck are not complete but what are available indicate that receipts by this method of transportation have increased to an even greater extent. It is also true that during the past few years, except 1936, when production was drastically

reduced by drouth, there was an increase in the supply of locally-grown produce.

Three important factors appear to be chiefly responsible for this growth; first, increased consumption of fresh fruits and vegetables, especially at the time of the year when locally-grown produce is not available; second, increased production of locally-grown products; and third, improved transportation facilities.

The population of the Louisville metropolitan area increased nearly 30 percent in the decade 1920 to 1930, and altho data for a later period are not available, estimates indicate that the number of people in the area is still increasing. It is also probable that

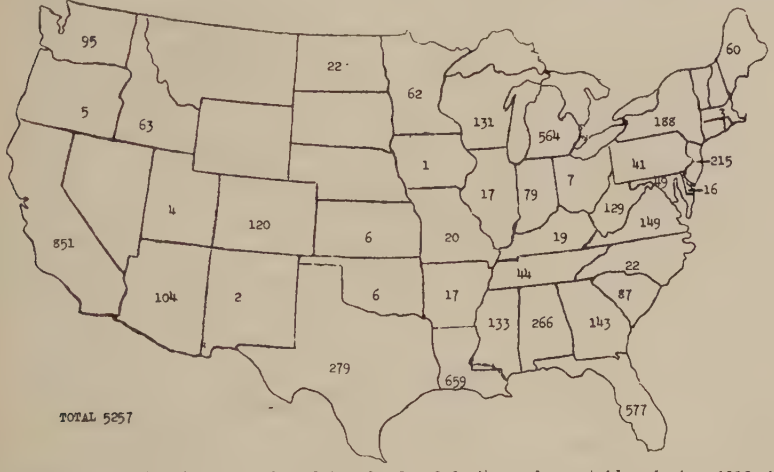

Figure 1. State of origin of carlot unloads of fruits and vegetables during 1936, in Louisville.

there was an increase in the per capita consumption of fruits and vegetables within the area, in keeping with the growing per capita consumption for the country as a whole.

The delineation of market areas under the most favorable conditions of research is at best an approximation of borderlines of the areas, as the extent of a market area shifts with changes in market conditions. Judging from the movement of produce into and out of Louisville and also by the location and arrangements of highways and railroads, the area represented in Figure 2, with production shown in Table 1, is territory from which, under normal conditions, surplus fruits and vegetables produced are sent to Louisville. Pro-

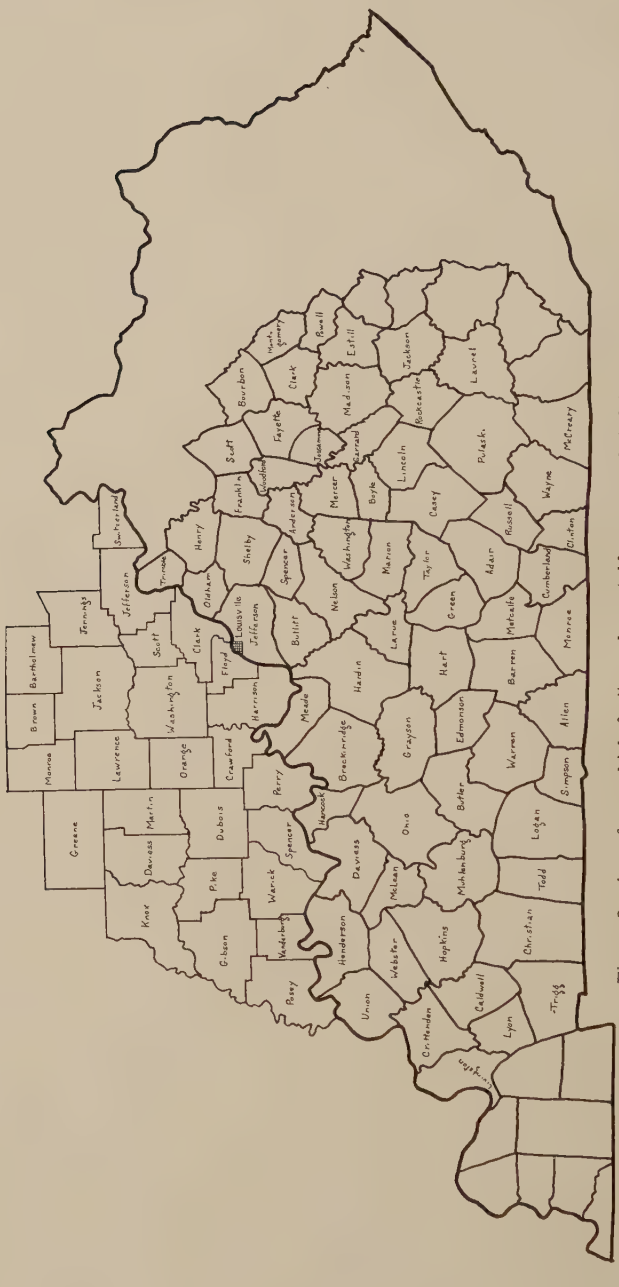

Figure 2. Area from which fruits and vegetables are marketed in Louisville.

duction of fruits and vegetables grown in the area tributary to Louisville has also shown considerable increase during recent years. Those commodities showing the greatest increase between 1920 and 1935 were cabbage, green corn, tomatoes, potatoes, sweetpotatoes, watermelons and strawberries. On the other hand, tree fruits all showed a decline. It is probable that further expansion will take place in the production of these products as there is an increasing demand for locally-grown produce.

No information as to the extent and growth of shipments of fruits and vegetables into or out of Louisville by motor truck is available, except the observations and opinions of persons on the market. Their judgment is that the importance of this type of transportation is growing, and that trucking may be relatively more important to the future growth of Louisville than to many other markets, because of Louisville's location with respect to markets situated in the Northern and Southern producing states. Located as it is, on important North-South arterial highways and midway between important northern and southern markets, Louisville is a

Table 1. Production of fruits and vegetables in Louisville market area

	1920	1930	1935
Fruits and vegetables harvested for sale, acres	26,121	50,499	73,769
Beans, acres	1,100	4,462	3,462
Cabbage, acres	674	1,364	1,896
Corn (sweet), acres	2,205	8,413	10,811
Tomatoes, acres	11,981	24,555	32,450
Watermelons, acres	3,603	3,574	10,259
Potatoes, acres	43,029	36,421	68,518
Sweetpotatoes, acres	8,217	7,299	14,927
Apples, trees of bearing age	3,489,344	2,286,575	2,077,813
Cherries, trees of bearing age	216,445	79,757	137,519
Peaches, trees of bearing age	1,545,570	1,523,112	1,448,018
Pears, trees of bearing age	252,145	183,757	177,778
Plums and prunes, trees of bearing age	236,830	122,557	111,878
Grapes, vines of bearing age	474,042	475,630	661,374
Strawberries, acres	3,169	4,834	5,160

From U. S. Census.

convenient point at which to exchange produce from the northern and southern areas. Thus the city becomes the terminus for fleets of trucks operating from the northern producing areas and from the southern producing areas. This situation provides opportunities that probably did not hitherto exist for the sale of locally-grown

fruits and vegetables, and lays the foundation for a large wholesale fruit and vegetable market which will not only serve the city of Louisville but will supply a much larger trade territory than is reached at the present time.

Locally-grown fruits and vegetables are included in this intercity trucking movement, altho to what extent is not clear. Nearly all locally-grown strawberries were shipped during the past three seasons by this mode of transportation. Grapes were shipped entirely by motor truck. Peaches and tomatoes shipped by growers cooperatively for the first time in 1935 were moved in the same manner. Out of 10,000 bushels of tomatoes, all but 3 carloads moved by truck and of 30,000 bushels of peaches only 7 carloads were shipped by railroad. Of less perishable commodities, the larger proportion of the commercial potato crop was moved out of the market by motor truck, in 1935 and 1936. This is shown in Table 2 for the four principal shippers.

Table 2. Disposition of locally-grown potatoes handled by the four principal dealers in Louisville, in 1935 and 1936. Carloads.

	Total 1935	Percent 1935	Total 1936	Percent 1936
Shipped by rail	216	29.4	14	8.3
Shipped by truck	373	50.8	90	53.6
Consumed locally	145	19.8	64	38.1
Total	734	100.0	168	100.0

The forces making for a larger volume of business in fruits and vegetables will probably continue to operate as in the past. Population of the metropolitan area will probably increase as wholesaling, manufacturing and commerce in the city and surrounding trade area develop. Trucking fruits and vegetables is gaining momentum and shipping perishables by rail continues to become more efficient. Production of locally-grown fruits and vegetables will increase as there are better local marketing opportunities, as local consumptive demand increases, as faster and more mobile shipping develops and as physical facilities are enlarged and made more efficient for exchange of locally-grown products.

ORGANIZATION OF THE LOUISVILLE FRUIT AND VEGETABLE MARKET

The Louisville fruit and vegetable market is organized similarly to other wholesale markets of like size and importance. A farmers' market place, correctly known as the Gardeners' and Farmers' Market, but commonly referred to as the Haymarket, provides the main outlet for locally-grown fruits and vegetables. Commission merchants and jobbers function chiefly to supply the local population and trade territory with fruits and vegetables shipped in from distant producing sections. These merchants also handle locally-produced fruits and vegetables in season and, when there is a surplus of locally-grown produce, find an outlet in other markets for it. A large proportion of locally-produced fruits and vegetables shipped out of the area is handled by farmers' cooperative marketing associations and produce exchanges. Three produce exchanges ship a large proportion of the commercial potato crop grown in the nearby communities of St. Matthews, Worthington and Buechel, and a cooperative fruit-growers association ships a large part of the strawberries, peaches and tomatoes destined for other markets. Selling by this association is done under agreement with a local commission merchant. During recent years, with the increase of motor transportation, a new type of middleman is developing to meet the needs of inter-city truckers. Altho the function of these middlemen is primarily to locate sources of local supply, some also handle incoming truck shipments on commission.

The present wholesale fruit and vegetable market is located in that part of the city generally devoted to wholesaling. It is known to have occupied the present location since 1892 when the Gardeners' and Farmers' Market was established, and since that time the volume of business has increased many fold. Changes and additions to facilities have been made from time to time to accommodate this expanding business, but in the absence of any plan for enlargement or reorganization, these changes were made only as a result of great congestion of traffic in the wholesale section or the pressure of other circumstances.

During this development the wholesale fruit and vegetable market became located away from railroad facilities. At present only one brokerage firm and the warehouses of three large chain

stores are located so as to have railroad facilities. All other wholesale dealers and jobbers, who handle fruits and vegetables, are located not less than three blocks from the nearest railroad unloading tracks, and some incoming produce is unloaded 15 city blocks from the wholesale section. (See Figure 3.) This lack of proper coordination of facilities necessitates extra handling of much produce received by rail, and a haul over crowded city streets to get to

Figure 3. Location of railroad unloading tracks in relation to wholesale district.

the places of business of most wholesale dealers. Yet, until recent years, the major movement of foods into and out of the market was by railroad and, as pointed out earlier in this report, several thousand carloads of fruits and vegetables are now shipped yearly by this mode of transportation.

Some further indication of the extent of handling and trucking is given in Table 3. For example, during 1934-1936, 69.9 percent

of the receipts of fruit and vegetables were unloaded at the team tracks located closest to the wholesale district commonly referred to as the Floyd Street, Jackson Street and Water Street district and

Table 3. Yearly unloads of fruits and vegetables on various team tracks in Louisville, 1934 to 1936.

	Average number of carloads	Percentage
Floyd, Jackson and Water Streets	3,156	68.1
14th Street, 9th and Broadway and private sidings	1,266	27.3
Market and 13th Streets	133	2.9
East Louisville	81	1.7
Total	4,636	100.0

located within three to six blocks of the wholesale district; 25.6 percent were unloaded at points from 9th to 14th Streets within a few blocks of Broadway, including the private sidings of two large chain stores companies; 2.9 percent were unloaded at the team tracks located in the vicinity of 13th and Market Streets; and 1.6 percent at the East Louisville team tracks located in the vicinity of the Baxter Avenue Station.

The handling of traffic has at all times been a problem with the growth of business and the substitution of motor trucks for horse drawn vehicles. Streets have been widened and improved from time to time and arterial highways constructed to connect Louisville with other markets, but farmers, wholesale dealers, and inter-city truckers still find that streets leading to the market area are congested during busy hours of the day and that delay is often experienced in getting thru traffic of the city on account of inadequate highways serving the market.

The increase of inter-city trucking has given rise to the need for facilities to expedite the exchange of fruits and vegetables handled by operators of trucks. To meet this situation the Gardeners' and Farmers' Market has designated a portion of their space as an inter-city truckers' market. A large open shed has been erected to protect the loads from inclement weather, a covered platform for loading trucks and some equipment to assist in grading and packaging produce for out movement, has been provided. The inter-city trucker wishing to sell his own produce can rent stalls on the market

either by the day or by the year. Those selling fruits and vegetables in this manner must procure a license from the city for which a charge of $20 per year is made.

Besides these facilities, certain commission men who have developed a business to handle truck receipts on commission have warehouses where produce can be unloaded, graded and displayed for sale. Here there is usually very little equipment for handling and no facilities for cooling fruits and vegetables.

Another type of middleman which has developed to meet this situation assists truck operators in locating sources of local supply for out shipments. These middlemen usually do not have warehouses or other facilities for handling fruits and vegetables but act merely as bargaining agents for truck operators. The common method of operation for such middlemen is to have offices situated near the market in Louisville, where supplies are located for the truck operator either by telephone or personal visits. At times produce displayed for sale on the Gardeners' and Farmers' Market is used as samples, while the product is actually purchased in the country by the truck operators. On the other hand, some of these middlemen establish themselves outside the city near local producing areas. A significant result of this whole situation is to decentralize the market. Altho such arrangements may be of immediate advantage to truckers and growers, it can be reasonably questioned whether the decentralizing effect on the market is desirable as a whole and in the long run.

Another significant result of congestion and the lack of proper coordination of physical facilities, has been the decentralization of the wholesale market and scattering of marketing facilities, especially those for handling shipped-in produce. The physical facilities of the three largest chain-store grocery systems, all of which handle locally-produced fruits and vegetables as well as those which are shipped in, and two cold storage plants, as shown in Figure 3, are located in other sections of the city several blocks from the wholesale districts.

LOUISVILLE AS A MARKET FOR LOCALLY-GROWN FRUITS AND VEGETABLES

Louisville is an important wholesale center for fruits and vegetables furnishing the main supply of these products not only for a

population of about 400,000 living in the metropolitan area, but also for a rather large population living in Central Kentucky and Southern Indiana. It is strategically located with respect to rivers, highways and railroads to receive fruits and vegetables from distant producing areas and to function as a distributing center for locally-grown produce thruout a large trade territory. Louisville is the principal wholesale market outlet for most of Kentucky lying East of the Cumberland River and West of the Mountain Area in Eastern Kentucky, excluding a few counties near Cincinnati. Several counties in Southern Indiana are also easily served by it.

The city is especially important as a market place for growers living within a distance of forty miles. This is shown by the results of interviews with 223 farmers on the market during 1935 and 1936. Nearly ninety-six percent of these farmers operated farms located within 30 miles of Louisville, while only 1.8 had farms located more than 40 miles from the market. (See Table 4.) When the data were broken down to include only regular patrons, it showed that their farms averaged only 12.5 miles from the market, while if occasional patrons were included, the average rose to 14.4 miles. One producer interviewed lived 180 miles from Louisville. Even tho occasional patrons live long distances from the market, the larger part of the production of locally-grown fruits and vegetables appears to be within easy trucking distance of the market. More particularly, most of the truck and small fruit growers who patronize the market live in Jefferson County in which Louisville is located. Of 384 growers who rented stalls on the Gardeners' and Farmers' Market

Table 4. Distance in miles traveled by growers interviewed on the Gardeners' and Farmers' Market.

Distance from Market	Number of growers	Percentage of growers in each group
Under 5	16	7.3
5 – 9	73	32.3
10 - 14	85	38.4
15 – 19	22	9.9
20 – 24	9	4.0
25 – 29	9	4.0
30 – 34	1	0.5
35 - 39	4	1.8
Above 40	4	1.8
Total	223	100.0

for the 1935 season, 306 lived in Jefferson County, 44 in other counties of Kentucky, and 34 in Indiana. (See Table 5.) Because the growers interviewed were selected at random, the authors believe them to be representative of the farmers who patronize the market. They represented all parts of the near-by market area as well as sections in outlying districts. (See Table 6.)

Many of the counties included in the Louisville market area excel in the production of fruits and vegetables. Strawberries are produced commercially primarily in Jefferson County, Kentucky, and Clark and Floyd Counties, Indiana. These counties produced 160,000 crates, or the equivalent of 400 carloads of strawberries in 1935. Production in 1936 was decreased drastically because of drouth, but the acreage devoted to the crop was not. Approximately half of the grapes produced in Kentucky are grown in Jefferson County where, in 1934, the production was 680,000 pounds.

Growers in Kentucky counties adjacent to Louisville shipped cooperatively in 1935, 30,000 bushels of peaches which, no doubt, represented less than 50 percent of the peaches produced in these counties. In addition to locally-grown peaches, growers in the vicinity of Henderson, which is about 150 miles from Louisville, sold 50,000 bushels of peaches thru the Jefferson County Fruit Growers' Association. These figures do not take into account peaches produced in the Indiana portion of the Louisville area which probably equal in amount those grown in Kentucky.

Jefferson and Oldham Counties produce about 25 percent of the potatoes grown in Kentucky. These counties, in 1930, produced 1,127,715 bushels of potatoes. On the Indiana side Clark, Floyd, Harrison and Duboise Counties produced a total, in 1930,

Table 5. Counties where producers live who rent stalls by the season on the Gardeners' and Farmers' Market.

County	Number of stalls	Percent of total
Jefferson	306	79.7
Bullitt	30	7.8
Oldham	8	2.1
Nelson	6	1.6
State of Indiana	34	8.8
Total	384	100.0

Table 6. Distribution by counties of producers interviewed on the Gardeners' and Farmers' Market during 1935 and 1936.

County	Number of growers interviewed	Percent of total interviewed
Jefferson	181	81.2
Bullitt	17	7.6
Hardin	4	1.8
Oldham	2	.9
Nelson	2	.9
Shelby	1	.4
State of Indiana	16	7.2
Total	223	100.0

of 311,675 bushels. Table 1, compiled from the 1920, 1930 and 1935 census, shows the production of fruits and vegetables in the Louisville market area.

THE GARDENERS' AND FARMERS' MARKET

Fruits and vegetables that are grown locally are sold primarily at the Gardeners' and Farmers' Market. They are also sold by growers direct to retail stores, to inter-city truckers, to hucksters and to wholesale dealers, but the principal method of disposal is at the public market.

The Gardeners' and Farmers' Market is a public market of the open, wholesale type, located in the center of the wholesale district (see Figure 4). The market place, consisting of parts of two city blocks with improvements, is provided by the Gardeners' and Farmers' Market Company, a stock corporation organized under the general corporation laws of Kentucky. The Market is constructed primarily to accommodate growers altho sale of fruits and vegetables is not restricted to growers or to persons selling locally-grown produce. The Market is organized to promote sale at wholesale but retail selling is permitted. Actually, wholesale business is carried on in the early morning hours and up to about 10 A. M., after which retail sales are made. Small retailers are permitted by the market company to occupy growers' places of business during the remainder of the day.

The facilities provided for growers consist of a series of platforms that can be used for the display of produce. Some of these platforms are nine feet wide and 12 inches above the driveway, while others, remodeled during 1936, are only three inches above

the driveway and arranged in a parallel manner so that trucks and vehicles can be backed into them. Sheds have recently been constructed over about half of the platforms to provide protection from the weather. On a lot adjacent to the market place, recently purchased by the market company, is provided a large shed for the sale of fruits and vegetables brought into Louisville by inter-city truckers. On this lot are also a loading shed, equipment for grading potatoes and onions, and an ice crusher, all of which facilitate the loading and grading of locally-grown produce in inter-city shipments.

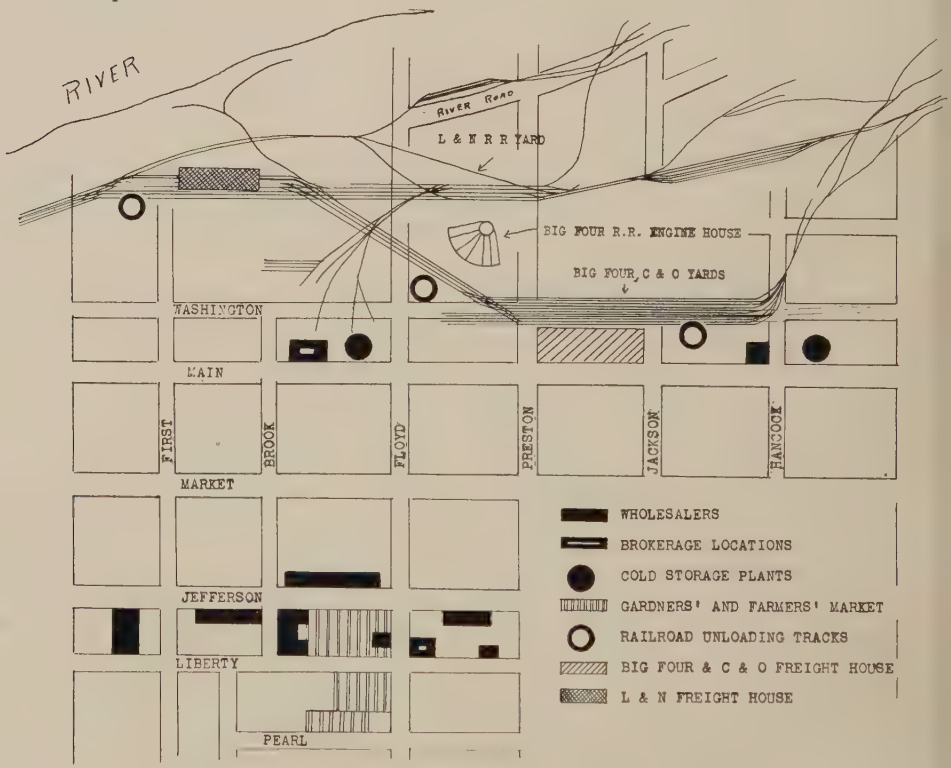

Figure 4. Wholesale fruit and vegetable district of Louisville.

Farmers patronizing the Market are of two general types, (1) those patronizing the Market regularly and (2) those marketing irregularly; the former generally rent space or stalls, by the season, the rent varying with the desirability of the location; the latter

rent space by the day and encounter the risk of having to accept less desirable space. Frequently, two growers cooperate in renting space and thus obtain at a lower cost to each, a desirable location on the Market. The first group of growers generally includes producers of a diversified assortment of fruits and vegetables who tend to locate near the Market. The occasional farmers, for the most part, come from greater distances and produce only one commodity for market, as green corn, tomatoes or melons. Of 150 such farmers located and living more than 50 miles from Louisville, 90 percent came from Indiana, mostly from those sections of Southern Indiana, where specialized production of green corn and tomatoes is practiced for local canneries.

The buyers on the Gardeners' and Farmers' Market are inter-city truckers, retail grocers, wholesale dealers, hucksters, and retail chain stores, named in order of importance. This conclusion is based on estimates of 106 growers who patronized the market in 1935. It is significant that approximately one-half of the growers reported inter-city truckers as their best customers. During 1936, however, when the supply of locally-grown produce was considerably reduced because of drouth and, in many cases, was of poor quality, inter-city truckers were not so important buyers as during the previous year.

It appears that nearly one-half of the products sold on the Gardeners' and Farmers' Market in 1935 were purchased by inter-city truckers. This was equivalent to about 1,400 carloads according to calculations of the authors. Retail grocers ranked second and wholesale dealers, including chain stores, ranked third. The total sales on the Gardeners' and Farmers' Market is thought to be conservatively estimated at the equivalent of about 3,000 carloads annually. This is well below figures calculated by officials of the market and by competent observers on the market.

The Gardeners' and Farmers' Market has provided a valuable and indispensable service for local growers of fruits and vegetables for more than forty years by furnishing a market place. The continued, widespread patronage of Kentucky and Indiana growers is evidence of its importance. However indispensable the market may be, many growers are still of the opinion that the organization and operation of the market are not adequately adapted to present

marketing requirements. For example, they point to the congestion of traffic that frequently exists in and near the market place, and the difficulty of approaching and leaving the market. Immediately, this situation is in part due to inadequate approaches, narrow driveways and narrow platforms for the display of wares and exchange of commodities offered for sale. In part it may also be due to the premature crowding of retailers into the market place in the morning or to failure of speculators to move out of the market place at the hour designated by the rules of the market, or before growers arrive at the market. The situation has been created by the growth in the volume of locally-grown fruits and vegetables, by the substitution of trucks for horse-drawn vehicles in farm marketing, and by the appearance of inter-city truckers as an important factor in the sale of fruits and vegetables. Rebuilding half of the old market place with new, wider and lower platforms and wider driveways was a big improvement. The development of a lot adjacent to the old market place as an inter-city truck market, with covered stalls and a covered loading platform, also tended to relieve the congestion of the market place, but has not solved the congestion of traffic caused by large trucks on the streets approaching the market place.

Farmers also complain about the amount of time required to dispose of their products. Growers who sold 289 loads during 1935 and 1936 indicated that they spent an average of 7.7 hours per load on the market. It took longer to dispose of a load during 1935 when supplies were large (8.7 hours) than during 1936 when the supply was reduced by drouth (7 hours). Detailed data are given

Table 7. Time required to sell a load of produce on the Gardeners' and Farmers' Market, 1935 and 1936.

Time	Number of growers	Proportion of growers
Under 5 hours	50	17.3
5 - 6.9 "	58	20.1
7 - 8.9 "	106	36.7
9 - 10.9 "	44	15.2
11 - 12.9 "	14	4.8
13 - 14.9 "	6	2.1
All over 15 hours	11	3.8
Total	289	100.0

in Table 7. Part of this difference was also due to the fact that in 1936 more than one-half of the producers who spent less than five hours on the market had only one commodity, such as strawberries; consequently they were able to dispose of this type of load much quicker than producers with mixed produce.

The crowded condition of the market occasionally accounts for the slowness of selling altho a more important reason appears to be the character of the buying. Grocers, hucksters, wholesale dealers and others buying for local consumption ordinarily obtain their daily requirements of fruits and vegetables during the early morning hours before retail establishments open for business whereas those agencies buying for out-of-city shipments must buy their supplies at a much earlier hour. This means that growers who wish to take advantage of this demand for home-grown products must arrive at the Market many hours earlier than when they were producing only for local consumption. The management of the Market, recognizing this situation, now permits growers to occupy their stalls from 10 o'clock in the evening until one o'clock in the afternoon of the following day. As the demand from out-of-city sources for locally-grown products increases, more growers follow the practice of reaching the Market late in the evening and spending the night or as long as is required to dispose of their produce.

There is no system of price quotations or market news for locally-grown fruits and vegetables, except as prices are quoted by a large wholesale merchant. These quotations represent prices at which jobbers are selling produce and not the prices being received by growers. Also very little progress has been made to adopt uniform containers and to standardize products. Products are, for the most part, marketed in a great assortment of containers; packs are not uniform as between growers, and quality of products varies widely. Much confusion exists as to prices; wide variations in prices for the same pack and quality often prevail on the market indicating the weak bargaining position of many growers because of an inadequate basis for bargaining and selling. Growers have continued to sell at the farmers' market, altho the basis of sale was unsatisfactory. Package, quality of products and market news take on new significance, however, as opportunity for export of locally-grown products appears. The present basis of sale may serve for

products destined for local consumption but it is wholly inadequate for a satisfactory and flourishing trade between cities.

WHOLESALE DEALERS

There are about 25 wholesale dealers of fruits and vegetables in Louisville. Several of these firms do a wholesale receiving and brokerage business in addition to jobbing; the others have a strictly local jobbing trade. Except for one firm which does essentially a carlot brokerage business, they are all located in the vicinity of the Gardeners' and Farmers' Market. (See Figure 4.)

These dealers are important outlets for locally-grown fruits and vegetables. Data obtained from them in this study show that in the aggregate they handle yearly the equivalent of 1,800 to 2,000 carloads of home-grown produce. Probably three-fourths of this amount is bought direct from growers at the dealer's place of business and the remaining one-fourth from growers at the Gardeners' and Farmers' Market. Products bought by the first method, are generally obtained by prearrangement with growers as to the time of delivery, quantity delivered and basis of price. For the most part, growers marketing by this method are the larger producers as well as those producing the better quality products. Moreover, they market in this manner because they believe that the amount of expense and labor required is less and the outlet more certain than when selling on the farmers' Market. It is interesting to note, however, that many of these farmers also sell fruits and vegetables on the Gardeners' and Farmers' Market in order to supply customers whose good will has previously been obtained.

Locally-grown fruits and vegetables bought by dealers are used chiefly to supply local retail trade and nearby small consumers' markets; few are shipped to other wholesale markets because when delivered by growers the products are not properly packed and graded for sale in large lots. Most Louisville dealers are not equipped to sort, grade, pack and otherwise handle miscellaneous supplies for sale in distant wholesale and jobbing centers.

INTER-CITY TRUCKING

In 1935, 38 operators of trucks were licensed by the City of Louisville to sell fruits and vegetables on the market. No license is required if the truck operator is only a purchaser. The number

increased to 111 in 1936. Many of these operators had more than one truck, so that there were considerably more trucks than licenses. Many of the truckers had headquarters in and operated from Louisville, altho fully half had headquarters in other markets.

In the absence of any central place for the exchange of commodities bought and sold by these dealers they do business in different sections of the market, altho they are most commonly found at a wholesale dealer's place of business or at the farmers' Market where, during 1936, a special part of the Market was designated as a place for them. Some truckers depend on wholesalers and jobbers to handle their produce. This is especially true of those truckers who visit the market irregularly and who do not wish to get a city license. A second group merchandise their own produce at the Gardeners' and Farmers' Market. Some occasionally contact retail stores as a means of disposal. Named in order of their relative importance the sources of home-grown produce purchased by truckers for shipment to other markets are: growers at the Gardeners' and Farmers' Market, wholesale dealers, and brokers who deal directly with individual growers.

Detailed information on receipts of fruits and vegetables were secured for April 27 to July 10, 1936.* During this period, at least 960 loads of produce were received by truck, 338 were sold on the Gardeners' and Farmers' Market, 513 were handled by wholesalers and commission men and 109 were delivered directly to chain stores. These receipts originated in 17 different states, altho 53 percent came from Georgia, Indiana and Michigan. Table 8 gives the states from which produce was received, and the number of truck loads from each.

Fruits and vegetables received by truck during May and June by commission merchants, at their places of business, by truck owners on the Gardeners' and Farmers' Market, and by the chain stores, amounted to 717 loads or the equivalent of 301 carloads. During the same period 1,058 carloads of fruits and vegetables were received by railroad. Thus about 3.5 carloads of produce were re-

*Data on inter-city truck receipts were gathered by the authors on the Farmers' and Gardeners' Market four or five days per week during the period. For the other days the data were collected by market officials. Data on truck receipts by commission merchants and wholesalers were secured by bi-weekly visits to their places of business. The two largest chain-store organizations furnished data on truck receipts by them, weekly during the period studied.

ceived by railroad for each carload received by truck during this period. It should be pointed out, however, that rail receipts for each of these two months were larger than for any other month of the year, while truck receipts were larger during the fall, so that for the year as a whole the ratio may be somewhat less.

Commodities most commonly trucked into Louisville in straight loads were potatoes, strawberries, apples, tomatoes and green beans. (Detailed information on commodities received and the amount in carloads is given in Table 9.) If the 1936 drouth had not reduced local production of most of these vegetables, truck receipts as well as rail receipts would probably not have been as large, but there is no measure as to what extent the drouth affected the movement.

Table 8. States of origin of inter-city truck receipts on the Louisville Market, April 27 to July 10, 1936.

	Number truck loads	Percent of total
Georgia	219	22.8
Indiana	157	16.4
Michigan	133	13.9
Ohio	75	7.8
Alabama	60	6.2
Florida	60	6.2
Tennessee	56	5.8
Mississippi	45	4.7
Illinois	41	4.3
Missouri	28	2.9
Kentucky	14	1.5
Wisconsin	3	
North Carolina	2	
Maryland	2	
Virginia	1	1.0
Oklahoma	1	
Louisiana	1	
Unknown	62	6.5
Total	960	100.0

Locally-grown fruits and vegetables were an important item in the out movement. However, the shipment of vegetables out of the market by motor truck was considerably less in 1936 than in 1935. During the two months of May and June, 1936, more than 100 truck loads of vegetables, mostly cauliflower, bunch beets, bunch turnips, kale, spinach, green beans, green peas, eggplant,

Table 9. Inter-city truck receipts* by commodities received on the Louisville market, April 27 to July 10, 1936.

Commodity	Number of carloads	Percent
Mixed vegetables	55.5	18.4
Potatoes	53.7	17.9
Apples	35.6	11.8
Tomatoes	31.5	10.5
Beans	27.7	9.2
Strawberries	26.3	8.7
Cantaloups	25.2	8.4
Peaches	16.6	5.5
Cabbage	13.2	4.4
Green Corn	2.2	.7
Lima Beans	2.2	.7
Watermelons	2.0	.7
Spinach	2.0	.7
Cucumbers	1.4	.5
Rhubarb	1.1	.4
Miscellaneous	1.0	
Peppers	1.0	1.0
Grapefruit	1.0	
Onions, leaf lettuce, celery, lemons, bunch turnips, oranges, sweetpotatoes, eggplant, and radishes	1.6	.5
Total	300.8	100.0

*Converted to carload equivalent.

and cabbage were moved out of the market by motor truck.* Of the less perishable commodities, the larger proportion of the commercial potato crop was moved out of the market by motor truck in 1934, 1935, and 1936. Supporting evidence based on the shipments of the four principal shippers, is shown in Table 2. Nearly all strawberries were shipped out by motor truck during the past three years. The same was true for grapes in 1934 and 1935. No grapes were shipped in 1936. Peaches and tomatoes shipped by growers cooperatively for the first time in 1935 were moved almost entirely by motor truck. Out of 10,000 bushels of tomatoes, all but 3 carloads moved by truck and of 30,000 bushels of peaches only 7 carloads were shipped by railroad.

Truck operators in the fruit and vegetable trade, in common with other classes of truck operators, have an important problem in obtaining cargoes. The peculiar problem of these operators is

*This does not take into consideration the truck loads of vegetables that were hauled directly from the field.

to get an outgoing cargo, as more of them are bringing products to sell than are coming to buy. Being engaged in the fruit and vegetable business they prefer to haul only fruits and vegetables. In fact, preference for hauling only these products is so strong that they often travel without cargo if fruits and vegetables cannot be had.

During the period, April 27 to July 10, 1936, 70 truck operators who hauled both into and out of Louisville were interviewed. They brought 127 loads of produce into Louisville while only 65 loads were trucked away. This corresponds closely with a survey made in 1935, when 22 truck operators estimated that they brought 1,638 truck loads of produce into the market annually but trucked only 667 loads away. The principal reasons for this difference between in-shipments and out-shipments appear to be (1) poor facilities for the exchange of locally-grown products, (2) seasonality of production of fruits and vegetables, and (3) non-uniformity of pack and grade which makes it difficult to get round lots of home-grown products suitable for wholesale trade in other markets. Altho the relative importance of these reasons is not known, it is reasonable to believe that growers and marketing agencies have not fully developed the opportunities offered by these inter-city truckers for marketing home-grown fruits and vegetables.

Another type of inter-city trucker does a jobbing business within convenient trucking distance, buying his supplies of fruits and vegetables in Louisville and selling them in small markets along the main highways. There are perhaps twenty such operators. Commonly they visit their customers daily, on one day they take orders, and go on to Louisville to get supplies to fill these orders. On the return trip the following day the goods are delivered. These truckers do not present any problem for the central market not already mentioned for other truck operators, but they do offer an increasingly important outlet for distribution of products grown in the vicinity of Louisville.

CONCLUSIONS

Conditions under which this study was made prevented a full appraisal of the market. Only those aspects of the market could be studied that were fundamental to a general understanding of the problems of fruit and vegetable marketing or for which data not

affected by drouth conditions were readily available. Consequently, it was not possible to study such important problems as the effectiveness of the market organization for facilitating exchange; prices of fruits and vegetables as related to quality of product and prices prevailing in other markets; efficiency of marketing as measured by costs of operation both of growers selling on the market and wholesale dealers; and seasonality of market movement of both locally-grown and shipped in produce. Further information is also desirable on the service of both rail and highway transportation, in order to point out their relative importance in relation to quantity of produce handled and standard of service to the market.

Further suggestions for improvement of the market mechanism cannot be offered until there is opportunity to analyze marketing problems, either stated or implied in the lines of research suggested. Such research might cause modification of any tentative conclusions which could be reached in this preliminary study, altho it does not seem probable that it would change the following general conclusions: first, that there is lack of proper coordination of physical facilities for efficient marketing; second, that an efficient system of exchange has not been perfected to utilize fully the opportunity offered by new developments in transportation, especially motor transportation; third, the basis for exchange, without standardization of locally-grown products and market news service, is entirely inadequate; and, fourth, the various business groups interested in the Louisville fruit and vegetable market have not taken full advantage of their opportunities to develop wholesale marketing of fruits and vegetables.

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THE PRESENCE OF AGGLUTININS FOR BRUCELLA ABORTUS IN MILK

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The Presence of Agglutinins for Brucella Abortus in Milk

By H. B. MORRISON and F. E. HULL

A few years ago an investigation was undertaken on milk from cows in the Kentucky Agricultural Experiment Station dairy herd which, at that time, contained both Bang's disease positive and negative cows. One of the tests made was the determination of the presence of agglutinins for *Brucella abortus* in individual milk samples from each quarter of the udder. Later, an opportunity was offered to continue this study in two large commercial dairy herds in Kentucky. The data in this paper are taken from the results obtained from these three herds.

CONDITIONS OF HERD MANAGEMENT

In Herd No. 1 the Bang's disease positive cows and Bang's disease negative cows were pastured in separate pastures and housed in separate barns about two hundred yards apart. The two groups were milked by hand and cared for by separate crews of men and thus had no contact with each other. The positive cows were mainly older cows which were kept largely because of their value as breeding stock.

Herd No. 2, while on one farm, was kept in two units designated as 2a and 2b, as they were located more than a mile apart and the system of management was considerably different. In Herd No. 2a, the positive and negative cows were kept in separate pastures but housed in the same barn. They entered the barn by different doors and a feed alley separated the positive and negative cows. All these cows were milked by hand by the same group of men. The cows in Herd 2b were pastured

and housed together. No attempt was made to keep them separated in the barn.

The positive and negative cows in Herd No. 3 used separate pastures but were housed in the same barn. They were kept together in groups in the barn with at least one vacant stall separating the positive and negative animals. One group of men handled both groups. Milking was done by machine. the same machines being used for both groups but the negative cows were milked first. The number of cows in each herd and the number of samples taken are shown in Table 1.

Table 1. Number of samples from individual quarters of the udder and number of cows from which samples were taken.

	Herd 1	Herd 2a	Herd 2b	Herd 3	All Herds
Positive Cows					
Number	51	9	27	12	99
Samples	197	35	100	116	448
Negative Cows					
Number	32	44	21	35	132
Samples	126	173	79	321	699
Total Cows					
Number	83	53	48	47	231
Samples	323	208	179	437	1,147

PROCEDURE

Milk samples were taken aseptically from each quarter of each cow's udder. The udder was washed and dried, and a few streams were milked from each teat and discarded. The milk for the samples was then collected in sterile glass containers. Samples for the agglutination test were later transferred to small test tubes containing approximately 0.01 gram of powdered rennet. The serum which exuded from the clot was used in the agglutination test. Determinations were made at a dilution of 1 to 50 by the rapid method using Huddleson *Brucella abortus* antigen. Agglutination reactions were recorded as negative, +, ++, +++, and complete. For the sake of brevity, the

+, ++, and +++ reactions are included under the heading, partial agglutination, in all tables except Table 7. The cows were classed as Bang's disease positive or negative according to the results of the latest blood agglutination test previous to the collection of the milk samples.

RESULTS

As might be expected in several herds under different systems of management, there was considerable difference in the percentage of milk samples from Bang's disease positive cows giving a positive agglutination reaction. As is indicated in Table 2 the percentage of samples giving partial and complete

Table 2. Distribution of agglutination in milk from cows in four herds, as percent of the number of samples tested.

	Herd 1 Percent	Herd 2a Percent	Herd 2b Percent	Herd 3 Percent	All Herds Percent
Positive Cows					
No agglutination	43.7	45.7	60.0	56.0	50.7
Partial agglutination	13.2	37.2	21.0	23.3	19.4
Complete agglutination	43.1	17.1	19.0	20.7	29.9
Negative Cows					
No agglutination	100	100	98.7	100	99.9
Partial agglutination	0	0	1.3	0	.1
Complete agglutination	0	0	0	0	0

agglutinations varied from 40.0 in Herd 2b to 56.3 in Herd 1, while the average for samples from all herds was 49.3 percent. In the samples from three of the groups there was a larger percentage of partial than of complete agglutinations at 1 to 50. However, because of the large majority of complete agglutinations in Herd 1, which was the largest herd, the complete agglutinations outnumbered the partial ones about three to two for the entire group. The larger percentage of complete agglutinations in this one herd may have been because it was composed of old cows which had been reactors for a longer time than the

others and so had more chance for their udders to become infected. Of six hundred and ninety-nine milk samples from Bang's disease negative cows only one (0.14 percent) gave any

Table 3. Agglutination reaction of milk from each quarter of the udder of Bang's disease positive cows.

Herd	Quarter of Udder	No. of Samples	Reaction		
			Negative	Partial	Complete
			Percent	Percent	Percent
1	LF	49	44.9	16.3	38.8
	LH	49	44.9	10.2	44.9
	RF	51	43.1	15.7	41.2
	RH	48	41.7	10.4	47.9
	All	197	43.7	13.2	43.1
2a	LF	9	55.6	33.3	11.1
	LH	8	50.0	25.0	25.0
	RF	9	44.5	33.3	22.2
	RH	9	33.3	55.6	11.1
	All	35	45.7	37.2	17.1
2b	LF	25	48.0	36.0	16.0
	LH	25	60.0	16.0	24.0
	RF	26	61.5	23.1	15.4
	RH	24	70.9	8.3	20.8
	All	100	60.0	21.0	19.0
3	LF	29	65.5	20.7	13.8
	LH	29	48.3	24.1	27.6
	RF	29	62.1	20.7	17.2
	RH	29	48.3	27.6	24.1
	All	116	56.0	23.3	20.7
All Herds	LF	112	51.8	23.2	25.0
	LH	111	49.5	16.2	34.2
	RF	115	52.2	20.0	27.8
	RH	110	49.1	18.2	32.7
	All	448	50.7	19.4	29.9

agglutination and in this instance agglutination was only partial.

When all the agglutination reactions are tabulated according to the quarter of the udder sampled (Table 3), there is about the same percentage of positive and negative reactions from each quarter. However, in three of the four herds there was considerable variation in this respect. In one herd the left front quarter and in another the right hind quarter showed the highest percentage of positive agglutinations. One herd gave about the same percentage of positive agglutinations for both hind quarters, the percentages from these quarters being higher than those from the corresponding front quarters, while the percentages of positive reactions were about the same from all quarters of the cows in the other herd. The left and right halves gave almost exactly equal percentages of positive agglutinations while the hind quarters gave a slightly higher percentage of positive reactions than did the front quarters.

A considerable difference was found in the agglutinin titer of milk from different quarters of the same cow's udder, as is indicated in Table 4. About one-third (36.2 percent) of the

Table 4. Distribution of agglutination in milk from individual quarters of the udders of positive cows.

	Herd 1	Herd 2a	Herd 2b	Herd 3	All Herds	Percent
All negative	16	1	12	13	42	36.2
Negative and partial	8	4	7	2	21	18.1
Negative, partial, and complete	3	1	1	4	9	7.8
Negative and complete	1	1	0	2	4	3.4
All partial	1	0	0	5	6	5.2
Partial and complete	5	2	5	0	12	10.3
All complete	17	0	2	3	22	19.0
Number of cows	51	9	27	29	116	100.0

Bang's disease positive cows showed no milk agglutination in any quarter of the udder, while nearly two-thirds (63.8 percent) gave at least partial milk agglutination in one or more quarters. The largest group of these (19.0 percent) showed complete agglutination in all quarters, followed closely by a group (18.1 percent) which gave negative and partial agglutinations. Other groups in order of size were those giving partial and complete (10.3 percent), negative, partial and complete (7.8 percent), all partial (5.2 percent) and negative and complete agglutinations (3.4 percent).

The number of cows giving negative agglutinations only, those with some partial but no complete agglutinations and those showing complete agglutination in one or more quarters is shown in Table 5. The duplicates, i. e., where more than one set of

Table 5. Agglutination reactions of milk from positive cows, showing number of cows with low and high titers.

	Herd 1	Herd 2a	Herd 2b	Herd 3	All Herds	Percent
All quarters negative	16	1	12	6	35	35.4
One or more quarters partial but none complete	9	4	7	0	20	20.2
One or more quarters complete	26	4	8	6	44	44.4
Number of cows	51	9	27	12	99	100.0

samples were taken from the same cow (in Herd 3) have been eliminated. In the entire group of cows about one-third gave no milk agglutination in any quarter while nearly one-half showed complete agglutination in one or more quarters. About twice as many cows showed complete milk agglutination as gave no higher than partial agglutination in any quarter.

Some idea as to the extent of the occurrence of agglutinins

thruout the udder is given in Table 6. Of the cows whose milk showed any agglutination, more than half showed agglutination

Table 6. Distribution of agglutination in milk from individual quarters of the udders of positive cows showing the extent to which the udder is involved.

	Herd 1	Herd 2a	Herd 2b	Herd 3	All Herds	Percent
All quarters negative	16	1	12	13	42	36.2
1 quarter positive	6	2	3	2	13	11.2
2 quarters positive	1	2	3	1	7	6.0
3 quarters positive	6	2	3	5	16	13.8
All quarters positive	22[1,2]	2[2]	6[3]	8	38	32.8
Number of cows	51	9	27	29	116	100.0

[1] One cow in this group had 2 blind quarters.
[2] One cow in this group had 1 blind quarter.
[3] Two cows in this group had 1 blind quarter.

in all the quarters giving milk, while the rest showed agglutination in milk from one, two or three quarters with at least one quarter negative. In only one case out of thirteen where agglutinins were demonstrated in milk from only one quarter was the agglutination complete. Approximately the same was true in cows having two quarters showing agglutination. By far the largest number of complete agglutinations occurred in cows whose milk from all quarters was agglutinated.

In nine of the thirteen cases where only one quarter was involved, agglutination was found in samples from hind quarters. The cases where milk from only one quarter was found negative were about equally distributed among the different quarters of the udder.

Two or more sets of samples were taken from some of the

cows in Herd No. 3. The results from these tests (Table 7) indicate the variability of the agglutinin titer of milk at different

Table 7. Agglutination reactions of milk taken at different times from Bang's disease positive cows.

Cow	Date	Reaction[1]			
		LF	LH	RF	RH
E 57 H	10/6/31	c	c	—	++
	11/16/31	—	c	c	c
	9/16/32	+++	++	++	+++
	10/4/32	++	++	+	++
	10/15/32[2]				
	12/7/32	+	+++	+	+
F 27 H	10/6/31	—	++	—	—
	11/17/31	—	—	—	+
	10/4/32	c	c	c	c
	12/7/32	+	+++	+	+++
E 8 H	10/21/31	—	—	—	—
	11/16/31	—	—	—	—
	9/14/32	—	—	—	—
E 22 J	10/13/31	—	c	c	++
	9/14/32	+	++	—	c
	12/7/32	++	++	++	++
E 69 H	10/19/31	—	c	++	c
	11/17/31	—	c	—	c

[1] —, negative; +, ++, +++, partial; c, complete.

[2] 10/15/32 Milk from individual quarters of E 57 was injected into guinea pigs. Milk from left hind quarter caused guinea pig to abort. Fetuses cultured — negative. Guinea pig autopsied and cultured — organism recovered. Inoculation tests by Miss Helen Harms, Assistant in Animal Nutrition.

times. In some instances, milk from one quarter of the udder showed no agglutination, while samples taken at other times from the same quarter showed complete agglutination.

DISCUSSION

In 1916, Cooledge (1) suggested the use of the agglutination test as a means of studying the presence of *Brucella abortus* in milk. From these and later experiments (2) he concluded that the udder participated in the production of agglutinins. This has since been confirmed by other workers (3), (4). The number of cases in which the cow's blood serum gives a positive titer and the milk a negative titer indicates that probably when the udder is not infected with *Brucella abortus* or other organisms, the blood agglutinins do not appear in the milk. On the other hand, it is well known that when organisms such as streptococci infect the udder and injure or destroy udder tissues, certain ingredients of the blood filter thru into the milk causing changes in its appearance, pH and composition. Thus, it might be possible for agglutinins from the blood stream of positive cows to get into the milk without a *Brucella abortus* infection of the udder.

The relation between milk agglutinin titer and presence of *Brucella abortus* in milk as demonstrated by guinea pig inoculation has been studied (5), (6), (7), (8), (9), (10) and (11). The investigators generally agree that the higher the milk titer the greater is the chance that *Brucella abortus* may be present in the milk. They do not agree on a significant titer; however, one (6) reports that milk from 69.2 percent of the cows examined, with a titer of 1 to 12.5 or over, contained the organism, while others report the milk titer of 1 to 100 or higher to be significant for the presence of the organism in milk.

Assuming that milk from a cow whose milk titer is 1 to 50 or higher may contain *Brucella abortus,* 44.4 percent of the positive cows in this study were apt to have the organism present in their milk at any time. Another 20.2 percent had milk titers of less than 1 to 50 while 35.4 percent gave negative titers in all quarters. Tweed (12) has shown the milk titer to change considerably in a relatively short time and our results corroborate this observation. In view of these facts it would seem safe to

expect that milk from any cow with a positive milk agglutination titer might contain *Brucella abortus* at any time.

SUMMARY

Agglutination tests were made on 448 samples of milk from separate quarters of the udders of 99 Bang's disease positive cows and 699 similar samples from 132 Bang's disease negative cows in the same herds.

Of the 448 samples from Bang's disease reactors 51 percent were negative, 19 percent showed partial and 30 percent complete agglutination at a dilution of 1 to 50.

The milk of 36 percent of the Bang's disease reactors gave no agglutination at 1 to 50 dilution; that of 5 percent showed partial; that of 19 percent showed complete agglutination and the milk of 40 percent showed differences in titer from different quarters of the udder.

The milk of 45 percent of the reactors, from one or more quarters of the udder, gave complete agglutination; that from 20 percent gave partial agglutination only.

When milk from only one quarter was agglutinated the agglutination was very seldom complete.

Milk samples taken at different times from the same quarter of the udder of the same cow showed considerable difference in agglutinin titer.

The percentage of agglutinations was slightly higher in milk from the hind quarters of the udder than in that from the fore quarters and complete agglutinations occurred oftener in milk from the hind quarters than in that from the fore quarters (33 and 26 percent). Difference in percentage of agglutinations in milk from right and left halves of the udder was not material (30 and 29 percent).

In only one sample out of 699 (0.14 percent) did milk from Bang's disease negative cows show any agglutination. In this instance the agglutination was only about 25 percent complete at a dilution of 1 to 50.

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APPENDIX

Table 8. Agglutinin titer of milk from separate quarters of the udders of cows that reacted positive to the agglutination blood test for Bang's disease.

Cow No.	Quarters of the Udder LF	LH	RF	RH
Herd No. 1				
0	c	—	c	c
1	c	0	c	0
2	—	—	—	—
3	—	++	—	—
4	c	c	c	c
5	+	c	—	++
6	—	—	—	—
7	++	—	+	c
8	—	—	—	—
9	—	—	—	—
10	—	—	—	++
11	c	c	c	c
12	c	c	c	c
13	—	—	—	—
14	—	—	—	—
15	c	c	c	c
16	—	—	—	—
17	—	—	—	++
18	c	c	c	c
19	—	++	—	—
20	—	—	—	—
21	c	c	c	c
22	+	c	c	c
23	c	c	c	c
24	c	c	++	c
25	—	—	—	—
26	c	c	+	c
27	—	—	—	—
28	c	c	c	c
29	—	—	+	0
30	—	—	—	0
31	+	+	+	+++
32	0	c	c	c
33	—	—	—	—
34	—	—	—	—
35	+++	+	+++	—
36	+++	+++	c	—
37	—	—	—	—
38	c	c	c	c
39	c	c	c	c
40	—	—	—	+
41	c	c	c	c
42	0	c	c	c
43	c	c	+++	c
44	c	c	c	c
45	c	c	c	c
46	—	—	—	—
47	—	—	—	—
48	c	c	c	c
49	+	0	+	—
50	+	c	c	c
Herd No. 2a				
44	—	—	—	—
45	++	+	—	+++
46	—	—	c	—
47	++	0	++	c
48	—	++	—	++
49	c	c	c	+++
50	—	c	+	—
52	+	—	+	+
53	—	—	—	+++
Herd No. 2b				
65	+	—	—	—
66	+	c	+++	c
67	+++	c	c	c
69	0	c	+++	c
71	—	—	—	—
72	++	—	+	—
73	—	—	—	—
74	—	—	—	—
75	—	0	—	—
76	—	+	—	—
77	—	—	—	—
78	—	—	—	—
84	+++	—	—	0
85	c	c	+	0
86	c	—	c	+++
87	+	+	—	—
88	+	++	+	—
89	c	0	c	c
90	—	—	—	—
91	—	—	—	—

Table 8—Continued

Cow No.	Quarters of the Udder			
	LF	LH	RF	RH
Herd No. 2b—Continued				
92	0	—	0	—
94	++	c	+	+
97	c	c	c	c
100	—	—	—	—
101	—	—	—	0
102	—	—	—	—
103	+	+++	—	—
Herd No. 3				
8	—	—	—	—
	—	—	—	—
	—	—	—	—
12	—	—	—	—
14	—	—	—	—
	—	—	—	—
22	—	c	c	++
	+	++	—	c
	++	++	++	++
23	—	—	—	—
	—	—	—	—
	—	—	—	—
24	—	—	—	—
	—	—	—	—
27	—	++	—	—
	—	—	—	+
	c	c	c	c
	+	+++	+	+++
29	—	—	—	—
	—	—	—	—
38	c	c	c	c
44	c	c	c	c
57	c	c	—	++
	—	c	c	c
	+++	++	++	+++
	++	++	+	++
	+	+++	+	+
69	—	c	++	c
	—	c	—	c

Legend. —, no agglutination; +, slight; ++ marked; +++, very marked; c, complete agglutination; 0, blind quarter; LF, left front; LH, left hind; RF, right front; RH, right hind.

Kentucky Agricultural Experiment Station

University of Kentucky

OIL-NICOTINE, A PROMISING NEW INSECTICIDE

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Bulletin No. 370

Oil-Nicotine, A Promising New Insecticide*

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Poisons for the control of insect pests fall into two main groups, the stomach poisons for chewing insects and the contact poisons for sucking insects. The most satisfactory stomach poisons are the arsenates of lead, calcium and magnesium, and certain fluorine compounds, applied as dusts and aqueous sprays. The most satisfactory contact poisons are nicotine sulfate, oil emulsions and lime-sulfur, applied in aqueous solution.

The arsenical and fluorine insecticides are poisonous to man, and this has led to the establishment of rigorous requirements by the federal government in regard to the amount of arsenical, lead, or fluorine residues which may be present on foods offered for sale in interstate commerce. The prospect of even smaller tolerances in the near future and the need for new insecticides less toxic to man have led to a nationwide study by chemists and entomologists of many possible compounds. As a result, several promising synthetic and naturally occurring organic compounds, such as certain thiocyanates, pyrethrum, rotenone, phenothiazine, and cyclohexylphenol, have been developed. Several novel methods of application have also been made available. One contribution from this Station is the development of oil-nicotine as a horticultural spray and its application by atomization. Because this new spray material shows promise of combining the merits of both contact and stomach poisons for a number of noxious insects, a preliminary account is given at this time.

HISTORY OF FORTIFIED ATOMIZED OILS

The use of atomized oils, fortified with pyrethrum or other toxic substances, as contact insecticides, is a recent development in eco-

* Preliminary report on a joint project of the Department of Entomology and Botany and the Department of Chemistry.

nomic entomology. As early as 1903, Volck (17) in California reported trying the application of oil by the use of an air blast. However, it was not until 1933, by the work of various California entomologists and Ginsburg (2, 6, 9, and 12) of New Jersey, that the efficacy of oil-fog sprays for horticultural purposes was shown. Up to the present, the main toxicant employed was pyrethrum of which the components of insecticidal value are Pyrethrins I and II. This material was incorporated into highly refined petroleum base oil by steeping the ground pyrethrum flowers in the oil or by adding a concentrated pyrethrum extract to the oil by the use of intermediate solvents. Recently, rotenone incorporated in oil has been tested by a number of workers and a patent for its incorporation was assigned to one of the pioneer companies in the development of household pyrethrum-oil sprays.

As early as 1929, R. H. Smith (15) of California reported adding nicotine to spray oil in which he claimed it was only very slightly soluble. He found a few suitable intermediate solvents, among which was butyl alcohol. All his efforts to fix nicotine permanently in oil failed.

In 1933, Le Pelley (11) reported attempting to extract the toxic principles of tobacco in oil but did not work out a satisfactory method of precedure. Also, in 1933, Herbert (9) published an account of the use of a light oil containing pyrethrum and nicotine, for spraying with airplane equipment.

Smith, Meyer and Persing (16), in 1934, used 95 percent free nicotine, dissolved in kerosene, gasoline and petroleum ether, plus alcohol as an intermediate solvent, as an atomized spray for the control of codling moth. They concluded that the material applied in that manner was impractical and turned their attention to a "Nicofumer" used to vaporize atomized free nicotine or nicotine sulfate in a portable fumatorium by means of pressure and heat.

The use of oil-nicotine as a horticultural spray was investigated in 1936 at the Kentucky Agricultural Experiment Station in a cooperative project between the Department of Entomology and Botany and the Department of Chemistry (14).

PREPARATION OF OIL-NICOTINE SPRAY

Ninety-five percent free nicotine held in a completely volatile, highly refined hydrocarbon distillate[1] by ethylene dichloride was used in the first tests. This mixture was homogeneous when first prepared but at the end of two days, in a 5 percent solution, brown droplets composed principally of water with some other impurities appeared on the bottom of the flask. One percent and 2.5 percent solutions of nicotine in the base oil, using 95 percent free nicotine and ethylene dichloride, remained stable for at least 10 days; after that time water and other impurities began to settle out.

It was found that 100 percent free nicotine was entirely soluble in several light, highly refined oils without the use of an intermediate solvent. The resulting solution was clear and appeared to be permanent. Commercial 95 and 50 percent free nicotine can also be used in the preparation of an oil-nicotine spray. When a sample of commercial 95 percent nicotine (by analysis 92.2 and 92.4 percent) was shaken with sufficient oil to yield a 1 per cent solution, a slightly cloudy mixture was formed. This was centrifuged and the clear, water-white solution of nicotine in oil separated from the brown aqueous deposit. The oil-insoluble material was found by analysis to contain only .119 percent of the total nicotine. The oil, then, by difference, contained .9988 per cent nicotine.

The base oil also took up almost all the nicotine from a 50 percent free nicotine (49.5 percent by analysis). The aqueous layer that separated after shaking contained 1.49 percent of the total nicotine, giving a .985 percent solution of nicotine in oil.

It appears from these results that the loss of nicotine in mixing small amounts of spray material is negligible when 95 and 50 percent free nicotine are used as sources of nicotine. The correct amount of 40 percent, 50 percent, or 95 percent free nicotine may be shaken in one container with the correct amount of oil, allowed to settle, and the resulting solution poured into the atomizer spray

1 The highly refined hydrocarbon distillate used in these tests will be referred to hereafter as the base oil. Unless otherwise mentioned, it has the following specifications:

Specific gravity	.775-.785
Saybolt viscosity at 100° F.	30 secs.
Flash point	170-180° F.
Initial boiling point	370-390° F.
Distillation end point	480-500° F.
Unsulfonatable residue	Above 98%
Color	Water white
Odor	Practically none

container. The dark residue left in the bottom of the first container may be discarded.

TOXICITY OF OIL-NICOTINE TO INSECTS

The first work with oil-nicotine, as mentioned above, was done with 95 percent free nicotine held in base oil by means of ethylene dichloride. It was found that nicotine in oil is much more toxic to insects than are comparable aqueous nicotine solutions. This is undoubtedly true because of the penetrating action of the oil and some additive toxic effect of the oil itself. A comparison of nicotine in oil and nicotine in water is given in table 1. The material was applied to adult green June beetles with a Devilbiss No. 16 atomizer.

Table 1. Relative toxicity of oil–nicotine and aqueous nicotine sprays applied to adult green June beetles.

Spray material	Percent killed	Number of insects	Number of tests
5% nicotine in water with spreader	none	15	3
2½% nicotine in water with spreader	none	15	3
5% nicotine in oil	100	40	8
2½% nicotine in oil	80	15	3
1¼% nicotine in oil	40	15	3
⅝% nicotine in oil	7	15	3
Oil only	none	15	3

Later, laboratory tests of oil-nicotine were made, using base oil to which 100 percent free nicotine had been added directly. The results of these tests and of others made earlier with ethylene dichloride as an intermediate solvent for 95 percent free nicotine, are given in tables 2 and 3. In some tests oil-nicotine was compared in toxicity with the base oil containing pyrethrum and rotenone, all containing equal amounts of the same intermediate solvent. In some, a modification of the apparatus described by Campbell and Sullivan (3) was used; in others, use was made of a small, continuous hand atomizer designed by Ritcher and Calfee.

In interpreting these results it should be remembered that only comparative toxicity between the materials is shown in the results of the bell-jar-settling mist tests, not the complete effectiveness of any material. The hand-sprayer tests more nearly approximate field conditions but here, too, an attempt was made to apply the materials in small enough amount to give low kills in the oil checks. It is of interest that nicotine in oil exhibited a spectacular knockdown that was much quicker than any other toxicant used.

Table 2. Relative toxicity of oil-nicotine, oil–pyrethrum and oil–rotenone, applied as a mist to insects under a bell jar.

Treatment	Percent killed			
	Imported cabbage worm	Pea aphis	Nasturtium aphis	Red spider
Oil–nicotine 2 percent	42	—	—	—
Oil–nicotine 1 percent	20	53	95	94
Oil–pyrethrum 0.2 percent	87	54	86	93
Oil–pyrethrum 0.1 percent	78	—	—	—
Oil–rotenone 0.2 percent	—	100	—	—
Oil only	17	6	19	—
Nothing	—	0	0	—

Table 3. Relative toxicity of oil–nicotine, oil–pyrethrum and oil–rotenone, applied to insects by means of a hand atomizer. Percent killed.*

Treatment	Cabbage looper	Southern cabbage worm	Imported cabbage worm	Tingids	Ham mite	Apple leaf hopper nymphs	Potato beetle	Mealy bug
Oil-nicotine 3%	98	—	—	—	100	—	—	—
Oil–nicotine 2½%	—	—	—	—	—	—	—	100
Oil–nicotine 2%	—	—	—	—	97	—	—	—
Oil-nicotine 1%	71	75	77	95	71	95	33	—
Oil–nicotine 0.63%	—	—	—	—	—	97	—	—
Oil–pyrethrum 0.2%	—	—	—	98	—	—	—	—
Oil–pyrethrum 0.1%	89	78	—	—	—	—	—	—
Oil-pyrethrum 0.05%	83	62	97	—	—	—	—	—
Oil–rotenone 0.2%	—	—	—	62	—	—	—	—
Oil only	28	18	—	64	70	31	—	—
Nothing	—	2	—	—	78	—	—	—

* See appendix for results in detail.

It is concluded from the tests reported in these tables and from field and greenhouse observations that nicotine in oil gives a high per cent kill of many kinds of insects. It also appears that 1 percent free nicotine in oil is about equivalent in toxicity to .1 percent pyrethrum in oil. Double this amount of pyrethrum was used in some tests but this strength was probably unnecessary since various workers agree that pyrethrum reaches its maximum toxicity at about .1 percent. One percent free nicotine in oil is about the right concentration for field work.

Other insects on which good kills were had with nicotine in oil are adult white flies, squash bug nymphs, adult blister beetles, thrips, stink bugs, and a number of common household and stored-products pests. The control obtained on mealy bugs, is illustrated by Figure 1. Both pots of lilies were originally heavily infested. The plant on the left was atomized with 1 percent nicotine in oil.

EFFECT ON PLANTS

Ginsburg (6, 7, 8), of New Jersey, and others (1) have shown that certain highly refined, volatile hydrocarbon distillates, alone and containing pyrethrum, may be safely applied to plants in the form of a fog. The writers found that free nicotine in similar oils also may be safely applied to plants, provided use is made of proper equipment. The plants to which nicotine in oil was applied as a fog without causing appreciable injury are apple, peach, grape, elm, lettuce, tomato, bean, radish, cabbage, turnip, sweetpotato, tobacco, red clover, morning-glory, nasturtium, marigold, zinnia, snapdragon, cosmos, rose, geranium, arbor vitae, and Scotch pine. Of these, lettuce, bean, sweetpotato, and clover are especially sensitive to overdose.

FIGURE 1. Mealy-bug infested lilies. The plant on the left was atomized with 1 percent nicotine in oil.

Since the oil used in these tests is highly refined and completely volatile, it is much safer on plants than less refined oils. Some hardy plants can be drenched with it and show no resulting injury. According to Ginsburg (7), chrysanthemums can be dipped in the oil without injury. The effect on foliage of applying 2.5 percent oil-nicotine with a semi-coarse continuous sprayer is shown in table 4.

Table 4. Comparative effect of oil-nicotine applied to plants with an atomizer and with a semi-coarse sprayer.

	Injury after spraying					
	With atomizer			With semi-coarse sprayer		
	24 hrs. after	7 days after	14 days after	24 hrs. after	7 days after	14 days after
Apple	0	0	0	0	xx	xx
Peach	0	0	0	0	xx	xx
Grape	0	0	0	x	xxx	xxx
Lettuce	0	0	0	xxx	xxx	xxx
Tomato	0	0	0	xxx	xxx	xxx
Bean	x	x	x	x	xxx	xxx
Radish	0	0	0	xxx	xxxx	dead
Red clover	0	0	0	x	xx	xxx
Nasturtium	0	0	0	xxx	xxx	dead

Legend: 0, no injury; x, very slight; xx, slight; xxx, considerable; xxxx, much.

Two types of burn are noticeable when excessive nicotine in oil is applied to foliage. The more usual type is where dead spots and blotches develop on the leaves wherever oil has penetrated. This injury can be detected almost immediately after treatment. The second type is an insidious one resulting from overdosing hardier plants or application at too low temperature for rapid volatilization. It is characterized by a loss of greenness and gradual yellowing of foliage. Such injury was found on drenched tobacco and lilies.

EFFECT ON ANIMALS

It is well known that nicotine is very toxic to warm-blooded animals.* Inhaled in extremely small quantity, it is a throat irritant and causes coughing. As much as 5 percent free nicotine in base

* **Not only are nicotine and its salts deadly poisons, taken internally, but they may produce serious poisoning if they come in contact with the skin. If a strong solution of nicotine is spilled on the skin, it should be washed off immediately with water. Oil–nicotine should be wiped off immediately and the skin washed with soap and water.**

oil was applied to plants, where there was adequate ventilation, without much discomfort to the operator. Against most insects, 1 percent free nicotine in oil is sufficient. A fog of this strength may cause slight throat irritation and headache if one remains in a closed greenhouse with the fumes for more than an hour. One percent can be used outdoors with impunity and also in the greenhouse if there is enough ventilation. Where strong dosages are used or where prolonged breathing is necessary, an effective mask for the nose may be made from several thicknesses of dampened cheesecloth. It is possible to mask the nicotine odor with pine tar or creosote odors but they do not prevent the throat irritation common to all nicotine sprays. One percent free nicotine in oil seemed less offensive to some observers than a 1:800 aqueous nicotine sulfate spray.

APPARATUS FOR APPLYING OIL-NICOTINE

Up to the present, use has been made of airplane equipment, blower vaporizers, compressed air and knapsack sprayers, for the application of atomized oils (4 and 5). Ginsburg (8) used a fog sprayer in many of his tests. All this equipment is available commercially only to a limited extent, the prices asked are excessive and the equipment is not entirely satisfactory.

It was found here that for small-scale use, a continuous atomizer (Fig. 2) was much more satisfactory than a continuous sprayer of the type used by Ginsburg. This atomizer does not drip and gives a steady flow of extremely small droplets, with little effort in pumping. Inasmuch as this continuous atomizer should have immediate commercial possibilities for household and garden use, it is described in some detail. Its construction is shown in Fig. 3. F represents the barrel, plunger and valve taken from an ordinary continuous sprayer. A is a metal air chamber permanently fixed to the barrel. The liquid reservoir B is attached inside A. There is no communication between the two. A small hole in the filling cap, E, subjects the liquid to atmospheric pressure. C is a copper tube leading from the bottom of the liquid-container to the air nozzle D. The orifices in both C and D are approximately .75 mm in diameter. C projects slightly past the perimeter of the opening D.

In operation, the forward action of the plunger forces part of the displaced air thru the opening D and compresses the rest in

chamber A, building up the pressure there. This pressure reserve, with the closing of the valve, causes a flow of air to continue thru D on the return stroke of the plunger. The continuous stream of air from A across C causes a lower atmospheric pressure in C, effect-

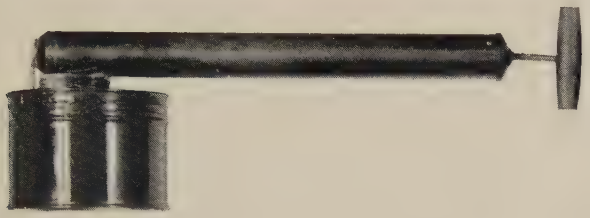

FIGURE 2. New continuous hand atomizer for the application of atomized oil to plants.

ing a rise of liquid to the tip. The stream of air at high velocity, passing the opening of C breaks up minute quantities of liquid into a fine, penetrating fog.

Small 2- to 4-gallon continuous sprayers for use in the garden

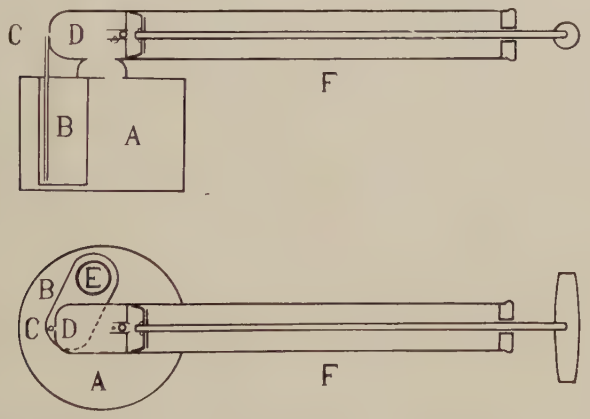

FIGURE 3. Construction of new continuous hand atomizer. A, air chamber; B, liquid container; C, liquid-delivery tube; D, air nozzle; E, filling cap; F, pump barrel.

may be easily adapted for use with atomized oils. An atomizer nozzle and liquid container may be screwed on the end of the spray rod and the 2- to 4-gallon tank used as an air-pressure tank. One pumping up of such a 3-gallon continuous atomizer was sufficient for 10 to 12 minutes operation.

For large-scale work, such as in greenhouses, a nozzle is needed

that produces a large volume of fog and still breaks up the oil into fine droplets. Several nozzles for this purpose, built on the principle of the Venturi tube, have been designed and used with both compressed air and steam. The new atomizing gun, the construction of which is shown in Fig. 4, is a device for greenhouse use.

In Fig. 4, A is an assembly drawing with parts as follows: 1. Cap nut, taper-drilled to form a tapered tube. 2. Short brass tube projected into the tapered tube. 3. Threaded section, brazed or threaded to 2, upon which 1 operates for adjustment of the Venturi effect. 4. Compression spring for holding the adjustment. 5. (In cross-section) Shows drillings for passage of air. 6 Small flexible metal tube, attached to 2 and 8 by either brazed or threaded unions. 7. Larger flexible metal tube similarly attached to 3 and to 11. 8. Oil-insecticide feed tube brazed or cast to 11 at point of emergence. 9. Screw cap to fit a standard can or glass container, either cast with or brazed to 11. 10. Insecticide container. 11. An aluminium or alloyed casting consisting of a short barrel, handle, and accessory parts as indicated. 12. Combination of air valve and air adjustment, trigger and accessory parts. 13. Air passage to the valve drilled in the casting 11. 14. Adapter either threaded or flared for the attachment of an air hose to a source of compressed air.

Operation. The compressed spring (d) exerts a force between (c) and (e) that holds the needle (g) tight against the valve seat (a). Rotation of (g) changes the position of (k), (i), and (j) which regulates the extent to which the trigger may be retracted and consequently the open position of (g) and (a).

C is a cross section of 11, the casting.

(a) Air chamber around the needle. (b) Drilled air tube offset to pass the trigger mechanism. (c) Slot in which the trigger operates.

The new atomizing gun operates on compressed air at pressures above 15 pounds. The air enters at 14 (A), passes thru 13 and the quantity is controlled and released, when desired, by the mechanism 12, and passes thru 7, around the edge of 2 and out thru the tapered tube, in 1 at high velocity. Low pressure is produced at the orifice in 2 giving suction that raises the liquid to the orifice where the air at high velocity atomizes the oil solution into a fine mist or fog with considerable carrying power. The droplet size of

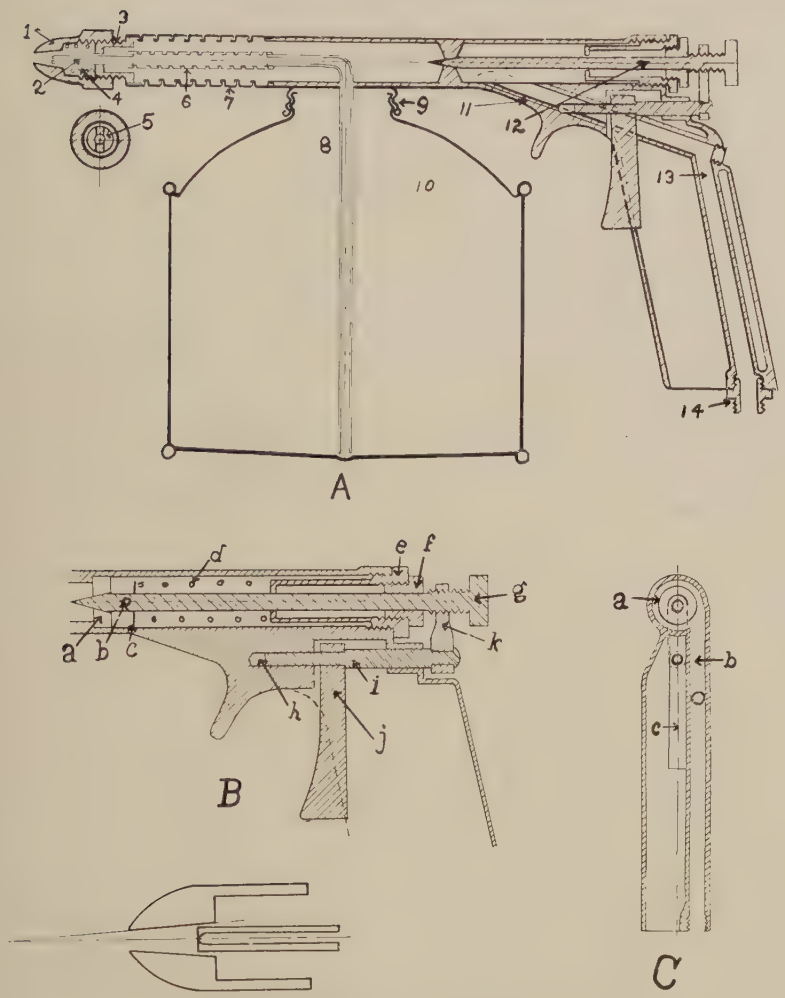

FIGURE 4. Construction of new atomizing gun.

B is a detailed drawing of 12, the air valve.

(a) Bronze valve seat driven into 11. (b) Cotter pin holding washer c. (c) Spring-retaining washer. (d) Compressing spring for closing valve. (e) Bushing (hex head) threaded to casting, drilled at closed end to allow easy movement of the valve needle. It contains packing. (f) Compression nut also drilled for the needle. (g) Needle with a knurled head threaded against the head. (h) Drilled hole in 11. (i) Shouldered steel rod. (j) Cast aluminium trigger, drilled to allow free movement of (i). It works thru a slot in 11. (k) A casting threaded for (g) at the upper end and drilled for (i) at the lower end. (g) Should work tight to hold adjustment. (k) rests against a shoulder on (i) and is firmly attached by riveting a head from the extremity of (i).

the fog produced by this device is well below that at which danger to foliage occurs. Flexible metal tubes are incorporated in the air and oil lines to facilitate spraying at different angles and the underside of foliage.

There are two main differences between the function of this new device and that of the paint-spray guns on the market. (1) This gun is designed to produce an extremely fine mist diluted with a large excess of air at high velocity to effect greater carrying properties and economy of solution, whereas paint-spray equipment gives heavy mist at low velocity with a view of applying the solution as rapidly as possible for even distribution.

(2) The principle of operation is entirely different. In this new equipment, the oil, under atmospheric pressure, is completely atomized at the orifice of the oil tube by the air at high velocity in the tapered tube. In paint spray guns, on the other hand, the liquid, under pressure, is mixed with air and the mixture forced thru a small orifice by the pressure behind it.

SUMMARY

Free nicotine dissolved in highly refined petroleum distillate shows promise as a horticultural spray. When correctly applied, it did not burn even tender plants and gave a high percent kill of many insects with piercing-sucking and chewing mouth parts.

It is concluded that 1 percent free nicotine in oil is suitable for field and greenhouse use with a minimum of discomfort to the operator, and is equivalent in toxicity to .1 per cent pyrethrum in oil.

It was found possible to dissolve free nicotine in oil by two methods. The first is by adding 100 percent free nicotine directly to the oil. The second is by shaking commercial free nicotine products, such as 50 percent water solution, with the oil and then separating the oil-nicotine from the settled water and impurities.

Nicotine in oil must be applied to plants in the form of a fine fog to avoid plant injury. Two new applicators have been devised and are described, one of which, a new hand continuous atomizer, appears to have immediate possibilities.

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APPENDIX

Table 5. Comparative toxicity of oil–nicotine and aqueous nicotine sprays.

Material	No. tests	No. insects	Percent killed
Check; oil plus interm, solvent	3	15	0
.63% free nicotine in oil	3	15	6.7
1.25% free nicotine in oil	3	15	40
2.5% free nicotine in oil	3	15	80
5% free nicotine in oil	8	40	100
2.5% free nicotine in water with spreader	3	15	0
5% free nicotine in water with spreader	3	15	0

Table 6. Toxicity tests of nicotine and other insecticidal materials in refined hydrocarbon distillate.

Insect	Material	No. tests	No. alive	No. dead
	Bell Jar-Settling Mist			
Nasturtium aphis	No treatment	2	26	0
	Oil check	1	29	7
	1% oil–nicotine	3	4	84
	.2% oil-pyrethrum	3	17	105
Pea aphis	No treatment	2	23	0
	Oil check	3	64	4
	1% oil–nicotine	6	35 (All paralyzed)	40
	.2% oil–pyrethrum	4	30 (All paralyzed)	35
	.2% oil–rotenone	1	0	11
Red spider	1% oil–nicotine	4	6	101
	.2% oil-pyrethrum	4	7	95
Imported cabbage worm	Oil check	3	25	5
	1% oil–nicotine	7	56	14
	2% oil-nicotine	2	14	10
	.1% oil–pyrethrum	4	9 (7 paralyzed)	31
	.2% oil–pyrethrum	3	4	26
	Hand Atomizer			
Imported Cabbage worm	1% oil-nicotine	3	8	22
	.05% oil–pyrethrum	3	1	29
Southern cabbage worm	No treatment	4	40	1
	Oil check	6	49	11
	1% oil–nicotine	6	16	45
	.05% oil-pyrethrum	6	23	37
	.1% oil–pyrethrum	6	13	47
Cabbage looper	Oil check	4	21	19
	1% oil–nicotine	4	4	36
	.05% oil-pyrethrum	4	7	33
	.1% oil–pyrethrum	4	1	39
Cabbage looper	Oil check	3	27	0
	1% oil–nicotine	3	16	13
	.1% oil-pyrethrum	3	6	18
Apple leaf hopper (nymphs)	Oil check	4	111	49
	.63% oil–nicotine	4	32	110
	1% oil–nicotine	4	6	195
Tingids	Oil check	2	21	38
	1% oil-nicotine	2	4	71
	.2% oil–pyrethrum	2	1	52
	.2% oil–rotenone	2	28	45
Mealy bug	2.5% oil–nicotine	1	0	73 adults 22 groups of young 49 egg masses
Potato beetle	1% oil–nicotine	5	16 (6 paralyzed)	8
Ham mite	No treatment	2	7	2
	Oil check	4	14	6
	1% oil-nicotine	12	41	97
	2% oil–nicotine	5	1	32
	3% oil–nicotine	2	0	21

Kentucky Agricultural Experiment Station

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CHONDRODYSTROPHY IN THE CHICK EMBRYO PRODUCED BY MANGANESE DEFICIENCY IN THE DIET OF THE HEN

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(61)

Figure 1. 1. Chondrodystrophic 21-day embryo. Note very short legs, "parrot beak," edema in the region above the atlas joint, globular contour of head and protruding abdomen.

2. Chondrodystrophic 20-day embryo. Note very short legs, "parrot beak" and globular contour of head

3. Chrondrodystrophic 21-day embryo. Note extreme edema involving the head and neck, very protruding abdomen, short legs and "parrot beak."

4. Chrondrodystrophic 21-day embryo. Note extreme shortening of mandibles and extreme edema of head and neck.

5. Chrondrodystrophic 19-day embryo. Note almost complete absence of down on the body small size, attachment of leg to the body from the tibial-metatarsal joint upward, and extremely short metatarsus.

6. Normal 21-day embryo.

Bulletin No. 371

Chondrodystrophy In The Chick Embryo Produced By Manganese Deficiency In The Diet Of The Hen

By MALCOLM LYONS and W. M. INSKO, JR.

Chondrodystrophy varies considerably in degree of expression as shown in Figures 1 and 2. The most common characteristics of chondrodystrophic embryos encountered in this study are (1) greatly shortened and thickened legs and shortened wings; (2) "parrot beak" resulting from a disproportionate shortening of the lower mandible and a downward curvature of the upper mandible; (3) globular contour of head apparently due to anterior bulging of the skull; (4) edema usually occurring just above the atlas joint of the neck and extending posteriorly for a variable distance, in some cases evident also in other parts of the body; (5) protruding abdomen apparently due to a relatively large amount of unassimilated yolk; (6) retarded down and body growth, particularly in the more severe cases (see Embryo No. 5, Figure 1).

Chondrodystrophy in the fowl seems to have been first reported by Landauer and Dunn (1926). Hutt and Greenwood (1929) found that the frequency of this abnormality from certain matings was as high as 34.78 percent of the eggs set in January but declined steadily to a complete absence in June. Munro (1932) found that the frequency of chondrodystrophy was definitely related to the season. The frequency of this condition decreased from 25.53 percent during the first part of March to 3.48 percent the latter part of May. Munro (1932) states " . . . the evidence is strong for believing the malformation to be due to genetic factors which depend upon unfavorable environmental conditions to become pheno-typically expressed."

Byerly, Titus and Ellis (1933) conclude that "Diets containing proteins from vegetable sources only increase the incidence of chondrodystrophy in the embryos of hens likely to produce such embryos." However, these authors did not find a seasonal distribu-

tion of this disorder as did Hutt and Greenwood (1929) and Munro (1932). Upp (1934) found the incidence of chondrodystrophy to be much higher in certain matings than in others, but no seasonal distribution of the disorder was noted. Byerly and co-workers (1935)

Figure 2. The effect of the injection of manganese directly into the egg, on embryonic development. Each consecutive pair (1-2, 3-4, and 5-6) is from eggs laid by the same hen within the same week. The eggs which produced embryos 1, 3, and 5 were not injected; those which produced 2, 4, and 6 were each injected with .03 mg of manganese. Numbers 1, 2, 4, and 6 are chicks, 3 and 5 are embryos that died on the 21st day of incubation.

report the occurrence of a type of chondrodystrophy distinctly different from the sporadic type referred to above, and have shown it to be definitely one of nutritional origin. These authors found that the disorder could be prevented by incorporating wheat germ and liver or wheat germ and whey in the ration of the parent stock. They also found that the nutritional chondrodystrophy could be prevented by allowing the parent stock direct sunlight and green range. Landauer (1936) gives an interesting histological description of the long bones in this disorder.

Patton (1937) reports that the glycine content of the muscles of

chondrodystrophic embryos (sporadic type) is much lower than that of the muscles of normal embryos.

The experiments herein reported were undertaken to determine the effect on embryonic growth and development, of feeding to laying hens a ration producing slipped tendon in chicks.

PROCEDURE

Sixteen Rhode Island Red pullets which had already started laying were selected from the Experiment Station flock and divided at random into two groups of eight pullets each. Each bird was placed in an individual compartment of an all-metal improvised hen battery, located in a room from which sunlight was excluded by covering the windows with tar paper. The room was artificially lighted twenty-four hours a day. An all-mash ration and tap water were given *ad libitum,* the water in glazed earthenware containers. The ration was of the following composition:

Ingredient	*Parts by weight*
Ground yellow corn	66.5
Dried skim-milk	15.0
Meat scrap	8.0
Steamed bone meal	5.0
Soybean oil	3.0
Sardine oil	2.0
Salt (NaCl)	0.5

This ration contained 1.4 percent phosphorus, 2.6 percent calcium and 5.5 parts per million (ppm) of manganese, and when fed to young chicks produces a high percentage of slipped tendon.

Lot 1 was fed the basal ration only, while Lot 2 received the basal supplemented by 40 parts per million each of manganese and zinc as the respective sulfates, and 100 parts per million of iron as ferrous ammonium sulfate. Manganese, zinc and iron were used in this connection because of the reported protective action of these elements in the prevention of slipped tendon (Wilgus and co-workers, 1936). Both lots were allowed oyster shell *ad libitum* but only a small amount of this material was consumed.

The eggs were gathered two or three times daily and pedigreed. After seventy-five days of this regime, each hen was stud-mated

every three or four days, usually with a White Leghorn male. Eleven males were used during the experiment. The males used at any given time were rotated between the pens each day. All eggs laid after the matings started were set at weekly intervals in one of three electric incubators and incubated under standard conditions of temperature and humidity for these machines. All eggs for each setting were incubated in the same machine and were hen-pedigree hatched. The eggs which failed to hatch were broken to determine fertility, the day of death of the embryo and its development.

RESULTS AND DISCUSSION

The hatchability and distribution of embryo mortality are shown in Table 1. The eggs produced by the hens fed the basal ration (Lot 1) gave a hatchability of only 5.2 percent as compared with 49.4 percent hatchability of the eggs from the hens receiving

Table 1. Hatchability and distribution of embryo mortality.

Lot No.	No. of fertile eggs	Treatment of eggs	Embryo mortality in percent of fertile eggs by weeks			Number of chicks	Percent hatchability
			1	2	3		
1	134	None	10.4	6.0	78.4	7	5.2
2	156	None	17.9	1.9	30.8	77	49.4
1*	25	None	20.0	8.0	68.0	1	4.0
1	21	Injected .03 mg Mn	19.0	0.0	42.9	8	38.1
1	6	Injected .03 mg Zn	0.0	0.0	100.0	0	0.0
2*	25	None	20.0	0.0	12.0	17	68.0
2	17	Injected .03 mg Mn	0.0	0.0	41.2	10	58.8
2	7	Injected .03 mg Zn	14.3	14.3	14.3	4	57.1

* These groups are tabulated separately from the bulk of the data of Lots 1 and 2 because they were the controls for the injection experiment.

Lot 1. Basal ration only. Lot 2. Basal ration plus 40 ppm each of Mn and Zn and 100 ppm of Fe.

the basal ration plus 40 ppm each of manganese and zinc and 100 ppm of iron. The seven chicks obtained from Lot 1 were all from the same hen and altho having short legs did not have slipped tendon. Seventy-eight percent (78.4%) of the embryos of the eggs from the hens in Lot 1 died during the last week of incubation, whereas only 30.8 percent of the embryos from Lot 2 died during the same week of incubation. Practically all embryos from Lot 1

that died during the last week of incubation did so on the 20th and 21st days. The embryos from the eggs of Lot 1 that died from the 10th thru the 21st day of incubation showed chondrodystrophy, while the embryos from the eggs in Pen 2 that died during this period showed normal skeletal development. These data are given in Table 2.

It seems clear from an examination of the data presented in Table 2 that this type of chondrodystrophy in the chick embryo is due to a mineral deficiency in the diet of the hen. Since Lot 2 was fed the basal ration supplemented with manganese, zinc and iron, it was not clear just which of these mineral elements was effective in the prevention of this disorder. Analyses of the eggs showed that those from the hens of Lot 1 contained much less manganese than those from the hens of Lot 2 which received the mineral supplement

Table 2. Incidence of short legs, "parrot beak," and edema.

Lot No.	Treatment of eggs	Dead embryos 10-21st day	Very short legs	Short legs	Parrot beak	Edema
			percent	percent	percent	percent
1	None	111	52.3	45.9	96.4	75.8
2	None	50	0.0	0.0	0.0	4.0
1*	None	19	57.9	36.8	100.0	57.9
1	Injected .03 mg Mn	9	0.0	0.0	0.0	22.2
1	Injected .03 mg Zn	6	83.3	16.7	100.0	83.3
2*	None	3	0.0	0.0	0.0	0.0
2	Injected .03 mg Mn	3	0.0	0.0	0.0	0.0
2	Injected .03 mg Zn	2	0.0	0.0	0.0	0.0

* These groups are tabulated separately from the bulk of the data of Lots 1 and 2 because they were the controls for the injection experiment.

Lot 1. Basal ration only. Lot 2. Basal ration plus 40 ppm each of Mn and Zn and 100 ppm of Fe.

(Table 4 to be discussed later). This together with the results of our studies on slipped tendon led us to suspect a manganese deficiency as the causative factor. Two methods are available for determining which element is responsible for the prevention of the abnormality. (1) By feeding the basal ration supplemented with the elements singly to groups of hens and determining the development of the embryos in the eggs thus produced. (2) By the direct injection of these elementts separately into eggs produced by hens fed the basal ration. The question could be answered most rapidly by the

latter method and the results obtained would perhaps offer more direct proof as to the deficiency. The latter method was employed with successful results.

The eggs laid in three consecutive weeks just prior to the termination of the feeding experiment were used in injection experiments. Those laid during the first two weeks of this three-week period were divided (by hens) at the end of each week into two groups as nearly equal as possible. One group was not injected (control)while .03 mg of manganese was injected directly into the albumen of each egg of the other. These eggs were placed in the incubator immediately following the injection. The eggs laid by each hen during the third week of this period were divided into three groups. One group of eggs was injected with .03 mg of zinc each, another with 03. mg of iron, while the third group was not injected. These mineral elements were injected as solutions containing 0.12 mg of the element per cc, manganese and zinc as sulfates and iron as ferrous ammonium sulfate. A small hole was drilled in the egg shell just over the air cell. The shell membranes were punctured with a small hypodermic needle and 0.25 cc (.03 mg of the element) of the particular solution injected directly into the albumen. A small circular piece of paper was sealed over the hole by the use of egg albumen. The eggs were incubated as previously described. Practically all the embryos from the eggs injected with iron died during the first week of incubation. The two embryos which lived beyond this state indicated that iron was not effective in the prevention of chon-

Table 3. Length of tibiae, metatarsi and humeri of chicks and 21-day embryos from eggs treated with manganese or zinc and from untreated eggs.

Lot No.	Treatment of eggs	No. chicks or 21-day embryos	Average length of tibiae	Average length of metatarsi	Average length of humeri
			mm	mm	mm
1	None	12	21.1	14.6	10.7
1	Injected .03 mg Mn	15	30.2	22.1	15.2
1	Injected .03 mg Zn	4	19.6	14.0	9.9
2	None	20	30.8	22.2	15.5
2	Injected .03 mg Mn	15	31.3	22.8	16.0
2	Injected .03 mg Zn	4	30.1	21.8	14.3

Lot 1. Basal ration only. Lot 2. Basal ration plus 40 ppm each of Mn and Zn and 100 ppm of Fe.

drodystrophy. Because of the small number these results are not tabulated.

The effects of other injections on hatchability and distribution of embryo mortality are shown in Table 1. The eggs from the hens of Lot 1, which were injected with .03 mgs of manganese per egg gave a hatchability of 38.1 percent as compared with 4 percent for the eggs not injected. Injections of .03 mgs of zinc did not improve the hatchability. The chicks which hatched from the eggs injected with manganese appeared normal in all respects.

Injections of zinc and manganese into the eggs produced by the hens (Lot 2) fed the mineral supplement did not improve hatchability or skeletal development.

All the embryos from the eggs of Lot 1 that were not injected showed chondrodystrophy whereas all the 10–21 day embryos and the chicks from eggs laid by the same hens during the same period but injected with .03 mgs of manganese per egg showed normal skeletal development. All the embryos from the eggs of this lot injected with zinc showed chondrodystrophy.

In order to obtain a more quantitative measurement of the effect of manganese on the skeletal development of the embryo, the tibiae, metatarsi and humeri of all chicks and 21-day embryos from the injection experiments were dissected out and the length carefully measured. These data are presented in Table 3.

The tibiae, metatarsi and humeri of the 21-day embryos and chicks from the eggs of Lot 1 which were injected with manganese were 51.4, 43.1 and 42.0 percent longer, respectively, than the same bones of those from the eggs which were not injected. The injection

Table 4. Manganese content of eggs as affected by the diet of the hen.

Sample	Sample collected days*	Manganese content in ppm of dry matter (100°) Lot 1	Lot 2
Egg yolk	27 – 28	0.90	1.28
Egg yolk	78 – 84	0.54	1.20
Whole eggs	85 – 91	0.56	0.96
Whole eggs	91 – 97	0.43	0.94
Whole eggs	98 – 104	0.54	0.84

* Number of days the hens had been on experiment when the samples were taken.

Lot 1. Basal ration only. Lot 2. Basal ration plus 40 ppm each of Mn and Zn and 100 ppm of Fe.

of zinc did not increase the length of these bones. The length of these bones of the embryos and chicks from the eggs of Lot 1 which were injected with manganese were essentially the same as those of the embryos and chicks from Lot 2, which was fed the mineral supplement. The disproportionate proximo distal reduction in the length of the long bones of the leg is interesting and is in agreement with the report of Landauer (1936) which states (in referring to chondrodystrophic embryos of this type) "In the legs the degree of reduction in the length of the long bones increases in the proximo distal direction." The effect of the injection of manganese into the egg, on skeletal development of the embryo is strikingly shown in Figure 2.

As stated earlier, manganese deficiency in the eggs of Lot 1 was suspected. Consequently composite samples of egg yolk and of

Table 5. Manganese content of the embroys, in parts per million of the material dried at 100° C.

Chondrodystrophic Lot 1			Normal Lot 2		
Number of embryos	Age days	Manganese ppm	Number of embryos	Age days	Manganese ppm
2 2	20 21	0.39	3	chicks	1.29
4	20	0.38	3	21	1.49
4	21	0.62	3	21	0.98
4	21	0.54	4	21	1.19
1 4	20 21	0.52	3	21	0.95
2 4	19 21	0.41			
1 4	20 21	0.43			
Average	—	0.47	Average	—	1.18

Lot 1. Basal ration only. Lot 2. Basal ration plus 40 ppm each of Mn and Zn and 100 ppm of Fe.

whole eggs (edible portion) from each of the two lots of hens collected at various times during the experiment were analyzed for manganese by the method of Skinner and Peterson (1930). Duplicate analyses were made. The results are presented in Table 4.

From an examination of these data it is readily apparent that the manganese content of the hens' diet very markedly affects the manganese content of the egg. This is one of the very few instances, wherein conclusive proof has been obtained of a deficiency of a mineral element in the diet of the hen being reflected by a restriction of the occurrence of the element in the edible portion (yolk and albumen) of the egg. The manganese content of eggs as reported in the literature varies greatly. Peterson and Skinner (1931) and McHargue (1925) reported, respectively, that egg yolk contained 2.3 and 1.5 ppm of manganese (dry matter basis). Bertrand and Medigreceanu (1920) and Peterson and Skinner (1931) reported, respectively, that whole eggs (edible portion) contained 2.52 and 1.1 ppm of manganese (dry matter). Part of this variation may be due to the different analytical methods employed. However, the hens producing these eggs were probably fed rations containing different amounts of manganese which would account for much of the variation.

Since the eggs which produced the chondrodystrophic embryos were shown to contain much less manganese than those in which embryonic development was normal, it seemed highly desirable to ascertain whether there was any difference in the manganese content of normal and chondrodystrophic embryos. Composite samples of chondrodystrophic (from Lot 1) and of normal embryos (from Lot 2) that died during the last three days of incubation were dried at 100° C after removal of all unassimilated yolk material from the body cavity, and analyzed for manganese by the method of Skinner and Peterson (1930). The findings are shown in Table 5. The manganese content of the chondrodystrophic embryos was consistently much smaller than that of the embryos having normal skeletal development. The thirty-two chondrodystrophic embryos which were analyzed contained an average of 2.4 micrograms* of manganese per embryo, whereas the thirteen embryos and three chicks showing normal skeletal development contained an average of 7.0 micrograms of manganese per embryo, thus affording further evidence that the malformation is caused by a deficiency of manganese in the egg.

* A microgram (γ) is one millionth of a gram (0.000001g).

GENERAL DISCUSSION

Several lines of evidence prove conclusively that the type of chondrodystrophy described in this paper is due to a deficiency of manganese in the egg. (1) The disorder was completely prevented by the addition of 40 ppm each of manganese and zinc and 100 ppm of iron to a ration which when fed to hens without the mineral supplement caused the production of eggs which gave chondrodystrophic embryos. Experiments now in progress show that the addition of 50 ppm of manganese but no zinc and iron to a ration containing approximately 5.5 ppm of manganese completely prevents chondrodystrophy in the embryo. (2) The hens from Lot 1, at the termination of the experiment, were transferred from the hen battery to a laying house on the Experiment Station farm. These hens were allowed direct sunlight and green range and were fed the regular Experiment Station laying ration, the mash of which is composed largely of wheat by-products and consequently contains a considerable amount of manganese. Forty fertile eggs produced by these hens between the fifteenth and thirty-third day, after removal from the batteries to these conditions, gave a hatchability of 87.5 percent, and all the chicks showed normal skeletal development. Thus it is shown that the hens soon cease the production of eggs producing chondrodystrophic embryos when proper alterations in the diet are made. (3) The complete prevention of chondrodystrophy by the injection of manganese directly into eggs which when not injected produced embryos showing this malformation, affords perhaps the most conclusive proof that this disorder is due to manganese deficiency in the egg. (4) Supporting evidence is afforded by the much smaller manganese content of the eggs from Lot 1 producing chondrodystrophy as compared with that of those from Lot 2 producing normal embryonic development, and by the much smaller manganese content of the chondrodystrophic embryos as compared with that of embryos having normal skeletal development.

The results of this investigation go far in the explanation of those obtained by Byerly and co-workers (1935). Before such an explanation becomes valid, it is essential to establish the identity of the disorder encountered in this investigation with that reported by these investigators.

The description given, and a comparison with the pictures shown, leave little doubt as to their identity. The peak of embryo mortality, short legs and wings, bulged head, parrot beak, straight tibiae and the disproportionate degree of reduction in the proximo distal direction in the length of the long bones of the legs described by Byerly and co-workers (1935) and by Landauer (1936) coincide with the characteristics of the chondrodystrophic embryos obtained in this study. The most characteristic differences between the sporadic and the nutritional type of chondrodystrophy aside from their histological differences, are that the former generally die during the second week of incubation, whereas, the latter show a peak of mortality during the last two or three days of incubation, and the sporadic type have bent tibiae while the tibiae of the nutritional type are not appreciably bent. In referring to these two types of chondrodystrophy Landauer (1936) states that "In many cases, . . . it would be difficult to distinguish these two types of malformed embryos on external appearance alone. Histologically these two types of micromelia are quite distinct."

Byerly and co-workers (1935) found that the nutritional type of chondrodystrophy could be prevented by allowing the parent stock direct sunlight and green range. It seems logical to assume that the hens on range consumed considerable green feed along with small amounts of soil and other materials containing considerable amounts of manganese, thus affording protection. The role of sunshine, if any, in the prevention of this disorder is not clear from the data available. The same authors found that meat meal and yeast were ineffective supplements for the prevention of the abnormality, whereas wheat germ was highly effective in this respect. These results seem easily explainable, since yeast and meat meal are relatively low in manganese as compared with wheat germ.

The same authors found that some of the short-leg embryos that hatch show unusual behavior in that there is a retraction of the head similar to that occurring in chicks with vitamin B deficiency. This condition was observed in one of the chicks (short legged) hatched from the eggs of the hens in Lot 1 (low manganese group). A large percentage of the short-legged chicks obtained in an investigation now in progress have a retraction of the head as described by Byerly

and co-workers (1935). This is additional evidence that the abnormality encountered by these investigators is identical with the one encountered in this investigation.

SUMMARY

The effect on embryonic development and hatchability of feeding to laying hens a ration producing slipped tendon in chicks, with and without a supplement of manganese, zinc and iron, is reported.

Eggs produced by hens fed the unsupplemented ration for 75 days gave a very low hatchability, with a peak of embryo mortality on the 20th and 21st day of incubation. The embryos that died after the tenth day of incubation were chondrodystrophic. Hens fed the same ration but supplemented with manganese, zinc and iron produced eggs giving good hatchability of normal chicks. The dead embryos from this lot showed normal skeletal development.

The hens fed the ration producing chondrodystrophic embryos, returned to the production of eggs supporting normal embryonic development within 15 days after they were transferred to farm conditions and allowed green range, direct sunlight and a ration containing considerable manganese.

The chondrodystrophic embryos were characterized by very short, thickened legs, short wings, "parrot beak," globular contour of head, protruding abdomen, and retarded down and body growth, particularly in the most severe cases. Very marked edema was noted in approximately 75 percent of these embryos.

The manganese content of the eggs producing chondrodystrophic embryos was much smaller than that of the eggs producing embryos of normal skeletal development.

Thirty-two chondrodystrophic embryos that died on the 19th, 20th and 21st day of incubation contained an average of 2.4 micrograms of manganese, whereas 13 embryos and 3 chicks showing normal skeletal development contained an average of 7.0 micrograms.

Chondrodystrophy was completely prevented by the injection of .03 mg of manganese directly into the albumen of eggs which when not injected produced embryos with this abnormality. The injection of zinc was ineffective.

The probable identity of this abnormality with that reported

by other investigators is discussed and a probable explanation of the results obtained by certain investigators is given.

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Kentucky Agricultural Experiment Station

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THE INCIDENCE OF STREPTOCOCCIC INFECTION IN THE UDDERS OF BANG'S DISEASE POSITIVE AND NEGATIVE COWS

BULLETIN NO. 372

Lexington, Ky.

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(77)

SUMMARY

Data are presented on the examination for streptococci and agglutination reaction of 710 milk samples drawn aseptically from individual quarters of the udder of cows in three herds. Three hundred and thirty-two of these were from 87 Bang's disease positive cows and 378 from 97 Bang's disease negative cows.

Distinctly different systems of management were used in caring for each herd which are described.

Streptococci were found in milk from 66.7 percent of the Bang's disease positive and 40.2 percent of the negative cows. Of the milk samples, 46.4 percent from the positive and 22.2 percent from the negative cows contained streptococci. The percentage of both cows and samples with streptococci was quite uniform among the Bang's disease positive cows in the three herds but varied widely among the negative cows.

Milk from 66.7 percent of the Bang's disease positive cows and 1.0 percent of the negative cows showed agglutination. From the positive cows, 50.6 percent of the milk samples showed agglutination while only 0.3 percent of the samples from negative cows were agglutinated.

From Bang's disease positive cows having streptococci in their milk from one or more quarters, 69.7 percent of the samples showed streptococci while 55 percent of the samples from a similar group of negative cows contained streptococci. The average number of infected quarters per cow was 2.7 for the positive and 2.1 for the negative cows.

Of the streptococcus infected Bang's disease positive cows 53.5 percent had three or more quarters infected while only 33.3 percent of the negative cows had three or more quarters infected.

No relation was found between the presence of streptococci and agglutination in the same sample of milk.

Streptococci were found in milk samples from all quarters of the udder about equally, altho there were a few more reactions in samples from the right side of the udder.

Agglutinations were distributed very evenly in milk samples from the different quarters of the udders.

Attention is called to the possibility of Bang's disease positive cows as a source of udder infection of negative cows.

Bulletin No. 372

The Incidence of Streptococcic Infection In the Udders of Bang's Disease Positive and Negative Cows

By H. B. MORRISON and F. E. HULL

Many recorded opinions have called attention to the large economic losses from Bang's disease and streptococcic mastitis. Most of these, however, have considered one disease or the other separately. The majority of workers have indicated that there is little, if any, relation between Bang's disease and streptococcic mastitis. These opinions are, no doubt, based on the fact that the organisms causing these diseases have been identified and each causes a specific disease independently of the other. It is a generally known fact, however, that *Brucella abortus* occurs in the udders of a high percentage of Bang's disease positive cows.

It has been shown by several workers (1, 2, 3, 4, 5,) that *Brucella abortus* may cause a low-grade or chronic interstitial mastitis. Very little information is found in the literature regarding the frequency of streptococcic infection of the udders of Bang's disease positive and negative cows. Thru the courtesy of the owners of two large commercial daries in the state an opportunity was extended to study the milk from the cows in their herds. Both of these herds contained Bang's disease positive and negative cows.

In herd No. 1, the positive and negative cows were housed in separate barns, cared for by different men, and grazed in different pastures so that there was no contact between the animals in the positive and negative groups. Even the breeding operations of the two groups were entirely separate, as a different set of bulls was used for each group. These conditions had prevailed for about four years when our samples were taken.

Herd No. 2 was divided into two groups which were housed in barns about a mile apart, on the same farm. These groups are designated Herd 2a and Herd 2b. The positive and negative cows in Herd 2a were kept in separate pastures but housed in the same

barn. The positive cows entered a different door from that used by the negative cows and were stanchioned on the opposite side of a feed alley from the negative group. No effort was made to keep the positive and negative cows apart in Herd 2b, either in the pasture or barn. The same men cared for both herds.

Table 1. Number of cows from which samples were taken, and number of samples from individual quarters of the udder.

	Herd 1	Herd 2a	Herd 2b	All herds
Positive cows	51	9	27	87
Samples	197	35	100	332
Negative cows	32	44	21	97
Samples	126	173	79	378
All cows	83	53	48	184
Samples	323	208	179	710

PROCEDURE

Milk samples were taken aseptically from each quarter of each cow's udder. The udder was washed and dried and a few streams were milked from each teat and discarded. The milk for the samples was then collected in sterile glass containers. Portions of these samples were incubated at least twelve hours at 37° C and examined for the presence of streptococci by the Breed technique. They were stained with Newman's stain. Those that contained chains of ten or more cocci were considered positive. The cows were classed as Bang's disease positive or negative according to the results of the latest blood agglutination test previous to the collection of the milk samples.

Samples of milk for determining the agglutinin titer for *Brucella abortus* were transferred to small test tubes containing about 0.01 gram of powdered rennet. After the milk had clotted, the serum which exuded from the clot was used in making the agglutination test. The test was made at a dilution of 1 to 50, by the rapid method, using Huddleson's antigen for *Brucella abortus*. Results of this test were recorded as complete, +++, ++, + and negative agglutination. The +++, ++, and + agglutinations are grouped under the heading, partial agglutination. All agglutinations given in this bulletin are for *Brucella abortus*.

RESULTS

The number of cows from which milk samples were taken and the number of samples are shown in Table 1.

The percentage of positive cows in whose milk streptococci were found was approximately the same in all three herds (see Table 2). The average of all herds showed that 66.7 percent of the positive

Table 2. Percentage of cows whose milk showed positive and negative reactions on examination for streptococci and agglutination.

	Herd 1		Herd 2a		Herd 2b		All Herds		
	Bang's dis. Pos.	Bang's dis. Neg.	Bang's dis. Pos.	Bang's dis. Neg.	Bang's dis. Pos.	Bang's dis. Neg.	Bang's dis. Pos.	Bang's dis. Neg.	All cows
Streptococci									
found	62.7	3.1	66.7	43.2	74.1	90.5	66.7	40.2	52.7
not found	37.3	96.9	33.3	56.8	25.9	9.5	33.3	59.8	47.3
Agglutination									
positive	68.6	0	88.9	0	55.6	4.8	66.7	1.0	32.1
negative	31.4	100	11.1	100	44.4	95.2	33.3	99.0	67.9

cows had streptococci present in milk from one or more quarters of their udders. A large variation was found, however, among the negative cows whose milk contained streptococci, in the different herds. Only one cow (3 percent) out of thirty-two in Herd 1 showed any streptococci while 19 (90 percent) out of twenty-one in Herd 2b showed this condition. The average of all negative cows showed that the milk of 40.2 percent contained streptococci. Of all the cows, both positive and negative, examined, milk from slightly over half (52.7 percent) contained streptococci and this organism was not found in milk from 47.3 percent of the cows. The same kind of an analysis regarding milk agglutination results indicates the percentage of Bang's disease positive cows showing agglutination of milk from one or more quarters to be 66.7 percent or exactly the same as for streptococci. Only one Bang's disease negative cow or 1 percent gave any milk agglutination. Slight agglutination was recorded on milk from only one quarter of this cow.

The reactions of the milk samples are shown in table 3. We again find the percentage of positive reactions for both streptococci and agglutination to be reasonably constant in each of the herds for the Bang's disease positive cows. Streptococci were found in a lit-

tle less than half (46.4 percent) of the samples and about half of the samples (50.6 percent) showed agglutination. In samples from Bang's disease negative cows, the percentage of samples increased progressively from the herd in which the positive and negative cows

Table 3. Percentage of milk samples that gave positive and negative reactions for streptococci and agglutination.

	Herd 1		Herd 2a		Herd 2b		All Herds		All
	Pos.	Neg.	Pos.	Neg.	Pos.	Neg.	Pos.	Neg.	cows
Streptococci									
found	43.1	.8	45.7	22.5	53	55.7	46.4	22.2	33.5
not found	56.9	99.2	54.3	77.5	47	44.3	53.6	77.8	66.5
Agglutination									
positive	56.3	0	48.6	0	40	1.3	50.6	.3	23.8
negative	43.7	100	51.4	100	60	98.7	49.4	99.7	76.2

were kept entirely apart to the herd in which the positive and negative cows were together at all times. Only one milk sample from a Bang's disease negative cow showed any agglutination and this sample came from the herd in which the positive and negative cows were not kept apart.

Samples from cows having streptococci in their milk are considered in Table 4. The percentage of samples containing strep-

Table 4. Percentage of milk samples positive and negative to streptococci, and percentage of the samples containing streptococci that were positive and negative to the agglutination test.

	Bang's disease positive cows				Bang's disease negative cows			
	Herd 1	Herd 2a	Herd 2b	Total	Herd 1	Herd 2a	Herd 2b	Total
Streptococci								
found	68.0	69.6	72.6	69.7	25.0	52.0	59.7	55.0
not found	32.0	30.4	27.4	30.3	75.0	48.0	40.3	45.0
Agglutination								
positive	56.8	60.9	35.6	50.2	0	0	1.4	0.7
negative	43.2	39.1	64.4	49.8	100	100	98.6	99.3

tococci from the Bang's disease positive cows in the different herds is surprisingly uniform. The difference between the highest and lowest groups was only 4.6 percent and the average for the positive group was 69.7 percent. The average for a similar group of Bang's disease negative cows was 55 percent.

Table 5 gives an indication regarding the number of quarters affected in the cows whose milk showed streptococci. Among the positive cows, the smallest group was that showing only one infected quarter and the largest group showed all quarters milking

Table 5. Extent of streptococcus infection in Bang's disease positive and negative cows.

	Bang's dis. pos. cows					Bang's dis. neg. cows					All Cows	
	Herd 1	Herd 2a	Herd 2b	Total	Percent	Herd 1	Herd 2a	Herd 2b	Total	Percent	No.	Percent
Streptococci found in												
1 quarter	5	2	2	9	15.5	1	6	6	13	33.3	22	22.7
2 quarters	9	1	8	18	31.0	0	8	5	13	33.3	31	32.0
3 quarters	9	0	2	11	19.0	0	3	5	8	20.5	19	19.6
All quarters ..	9	3	8	20	34.5	0	2	3	5	12.9	25	25.7

to be infected with streptococci. The opposite was true of the negative cows altho there were an equal number of cows having one and two quarters affected. The average number of infected quarters for the positive group was 2.66 per cow while that for the negative group was 2.1 infected quarters per cow. Four percent of the quarters on the positive cows were blind and 2.6 percent of the quarters of the negative group were blind.

The results of agglutination tests made on the same milk samples from the positive cows were tabulated in combination with the results of the examination for streptococci in Table 6. Of four possible combinations of reactions, the largest group was that in which streptococci and agglutination were found in milk from the same cow. The smallest group consisted of the cows in whose milk neither streptococci or agglutination were noted. Among the cows whose milk from one or more quarters was agglutinated, the ratio of the streptococcus negative to streptococcus positive cows was 1:1.9,

Table 6. Percentage of cows and samples of milk that reacted to streptococcic and agglutination tests in Bang's disease positive cows.

	Cows				Milk samples			
Reactions	Herd 1	Herd 2a	Herd 2b	Total	Herd 1	Herd 2a	Herd 2b	Total
S+A+	43.1	66.7	37.0	43.7	23.8	34.3	20.0	23.8
S—A+	25.5	22.2	18.6	23.0	32.5	14.3	20.0	26.8
S+A—	19.6	0	37.0	23.0	19.3	17.1	33.0	23.2
S—A—	11.8	11.1	7.4	10.3	24.4	34.3	27.0	26.2

while for the cows whose milk showed no agglutination this ratio was 1:2.2. Comparing streptococcus positive and negative cows, the ratio of cows whose milk showed no agglutination to those whose milk was agglutinated was exactly the same as in the above mentioned combinations. A similar tabulation of the results on individual milk samples shows all of the groups to be approximately equal.

Table 7. Agglutinin titer of milk samples from Bang's disease positive cows as percent of the number of samples tested.

Agglutination reaction	Streptococci present				No streptococci			
	Herd 1	Herd 2a	Herd 2b	All Herds	Herd 1	Herd 2a	Herd 2b	All Herds
Complete	45.9	37.5	20.7	36.4	42.0	0	17.0	30.9
Partial	9.4	37.5	17.0	14.9	15.2	36.8	25.5	20.2
Negative	44.7	25.0	62.3	48.7	42.8	63.2	57.5	48.9

The effect of the presence of streptococci on the agglutinin titer of the milk samples is shown in Table 7. In the milk samples containing streptococci there were 5 percent more complete and 6 percent less incomplete agglutinations than in the milk samples free from streptococci. The percentage of samples showing no agglutination was about the same in both instances.

A summary of the samples showing the presence of streptococci and agglutination according to the quarter of the udder in which they occurred is given in Table 8. The samples containing strep-

Table 8. Distribution of streptococci and agglutination in the udder, as percent of the number of samples tested.

Quarter	Samples containing streptococci Bang's disease Positive cows	Bang's disease Negative cows	All cows	Samples agglutinated Bang's disease Positive cows
LF	38.6	25.8	31.8	53.0
LH	45.1	18.3	30.9	50.6
RF	50.6	24.0	36.5	50.6
RH	52.5	20.8	35.2	50.6

tococci are fairly evenly distributed among the different quarters of the udder. A slightly higher percentage of infected quarters occurred in the right half of the udder than in the left but the dif-

ference is probably not significant. The agglutination reactions are quite evenly distributed among the various quarters.

DISCUSSION

The above data are of interest from several standpoints; first, the higher incidence of streptococcic infection among Bang's disease positive than Bang's disease negative cows; second, the larger percent of streptococcus infected quarters per cow among the positive cows; third, the relationship or lack of relationship between the presence of streptococci and agglutination reaction in milk from the same quarter of the udder; and fourth, the results of different systems of management of herds containing both Bang's disease positive and negative cows.

The three herds examined varied considerably in size and proportion of Bang's disease reactors and yet the percentage of cows and milk samples in which streptococci were found were very nearly the same in all three herds. Our average of 46.4 percent of the milk samples streptococcus positive agrees very closely with that reported by Hucker, Trudell and Jennings (6) (48 percent) in 221 cows condemned by the tuberculin test. In a study of 92 cows Sholl and Torrey (3) found that milk from 63.4 percent of 41 Bang's disease positive and 19 suspicious cows contained streptococci. Their results with positive cows are quite similar to ours altho their findings for negative cows indicate a higher percentage of negative cows with streptococcic infection than do ours.

In a report on eradication of abortion Simms et. al. (7) report the occurrence during a three-year period of 31 cases of garget among 44 Bang's disease reactors and only 2 cases among 27 nonreactors. Graham and Thorp (8) stated that "garget or inflammatory conditions of the udder marked by clotty or bloody milk are frequent complications in abortion-infected animals." Elder (9) thought that *Brucella abortus* infection might act as a predisposing cause and pave the way for the entrance of streptococci and other organisms which seem to be most important in the causation of bovine mastitis. Our results further indicate that cows suffering from Bang's disease show a higher incidence of streptococcic infection of the udder than do Bang's disease negative cows in the same herd

when the herd is properly managed. It would seem that in herds such as Herd 2b where no attempt was made to keep the Bang's disease reactors separated from the non-reactors, the positive cows contributed materially to the infection of the udders of the negative cows.

In addition to a higher percentage of Bang's disease positive cows showing streptococci in their milk, the average number of infected quarters per cow was higher among the streptococcus positive Bang's disease reactors than among the non-reactors. This is true for each herd as well as the total. More than half of the reactors had streptococci in three or more quarters while only one-third of the non-reactors showed streptococci in more than two quarters.

There was apparently no interdependence between the occurrence of streptococci and agglutination either in the individual cow or in individual quarters of the same cow. In other words, two-thirds of the Bang's disease positive cows showed streptococci in milk from one or more quarters and a like number showed agglutination of milk from one or more quarters. Of the positive cows showing streptococci in their milk about two-thirds showed agglutination for *Brucella abortus* in the milk. Furthermore, about two-thirds of the cows showing milk agglutination gave milk containing streptococci. The idea had been suggested that possibly in the case of udders which had been injured by streptococci to such an extent that some of the blood substances were able to filter thru into the milk, agglutinins for *Brucella abortus* might appear in the milk in this manner. Apparently this did not happen to any extent in these samples as the proportion of samples showing agglutination to those showing no agglutination was almost exactly even both in the case of the samples containing streptococci and those not containing streptococci. The agglutinin titer of the samples which were agglutinated from the cows whose milk showed streptococci averaged a little higher than those from the cows whose milk did not show streptococci.

It is not the intention of the authors to discuss in this bulletin, methods of managing Bang's disease infected herds as this is done in another publication from this Station (10). The data presented give a graphic evaluation of three different systems of manage-

ment. The care received by Herds 1 and 2a was excellent while that of Herd 2b was not up to the high standard of the other two groups. This may account for some but certainly not all of the differences between it and the other two herds. The care received by Herd 2b was probably typical of that received by many better than average farmers' herds thruout the country. The results emphasize the fact that, if Bang's disease reactors are to be kept at all, they should be segregated not only to prevent the spread of Bang's disease but also to prevent the spread of mastitis. If this is not done the Bang's disease may furnish a second serious threat thru the spread of streptococci and mastitis.

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Kentucky Agricultural Experiment Station

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ALBUMINURIA AND NEPHRITIS IN DAIRY COWS

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Bulletin No. 373

Albuminuria and Nephritis in Dairy Cows

By H. J. METZGER, F. E. HULL and FORDYCE ELY

INTRODUCTION

This is a study of the occurrence of albuminuria and nephritis in the Kentucky Agricultural Experiment Station dairy herd from October, 1930, to April, 1937. This herd is a good subject for such an investigation. All the animals considered in this study were bred and reared on the farm, the last purchased female having been added to the herd in 1925. The health of the herd has been under the close supervision of the members of the staff of the Department of Animal Pathology since September, 1928. A record of all of their work with the herd has been kept in a health book. Except cows numbers E 29, E 41, E 53, E 55, E 68 and E 70, the health record of all animals considered is complete from birth. The herd has been free from tuberculosis since 1920 and the eradication of Bang's disease, which was started in 1928, was completed in January, 1933. Since that date all suspected animals have been immediately removed from the herd.

During the period under consideration this herd has averaged 62 cows and heifers of breeding age. The distribution of these animals according to breed is shown in Table 1.

Table 1. Number of cows and heifers of breeding age in the herd, 1930 to 1936, inclusive. Distributed according to breed.

Year	Jersey	Holstein	Guernsey	Total
1930	42	15	10	67
1931	41	15	8	64
1932	38	20	8	66
1933	42	21	3	66
1934	39	17	2	58
1935	42	15		57
1936	40	18		58
Total cow years	284	121	31	436
Percent of total cow years	65.1	27.8	7.1	

Except the milking herd, the three breeds were maintained exactly alike. All cows and heifers had access to typical bluegrass pasture from about the first of April to the middle of November. Cows in milk always received grain in proportion to their production. The grain mixtures thruout the entire period were as follows:

On fresh green pasture	4 parts corn 2 parts wheat bran 1 part cottonseed meal
On older pasture and dry hay	3 parts corn 2 parts wheat bran 1 part cottonseed meal

Two percent steamed bone meal was added to each of these mixtures.

The cows all calved in the same stalls and the calves were housed in the same barn. It was not unusual to let calves of two breeds occupy the same stall. The heifers were fed and housed exactly alike. While many of the sick animals were segregated, this was not done with those that showed albuminuria or symptoms of nephritis.

The early examinations of the urine were made by Dr. Daniel J. Healy who carried on this work from 1930 to the time of his death in November, 1934. His work may be divided into two periods. The first extends from October, 1930, thru January, 1931. Thirty-seven cows and heifers were examined. Some of the animals which showed albuminuria were followed up with frequent examinations after this period. It is interesting to note that these early examinations were made partly because of the insistence of the superintendent of the dairy herd that "some of the cows had bad kidneys."

The second period began in April, 1932. The urine from all heifers under one year of age, at this date, was examined monthly for a period varying from eight months to two years. These examinations were part of the work done on a project which was instituted to study reasons for delayed conception and sterility in dairy heifers.

No examinations were made from the time of Dr. Healy's death until April, 1935, when the work was taken up by the senior author.

Since then urine samples have been examined as often as practicable.

Since the start of the work, 1545 samples of urine from 156 animals have been examined. No effort was made to select these samples with respect to breed. Sixty-six percent of the animals examined were Jerseys and 29 percent were Holsteins. This distribution corresponds very closely with the proportions of these two breeds in the herd during this period, shown in Table 1. During the early part of the work, no effort was made to examine every cow but since 1935 the urine from all females in the herd has been examined at least four times a year.

METHODS

Most of the examinations reported by Dr. Healy include values for pH, specific gravity, ammonia nitrogen, calcium, and sulfur. The senior author has made determinations for various constituents of the urine. Because of the desire to present this work largely from a pathological and clinical view point these data will be considered in a later publication.

Dr. Healy determined the albumin in the urine by the heat and acetic acid coagulation. His results are reported as "Trace" "Present" and "Marked." Since April, 1935, a quantitative method described by Kingsbury, Clark, Williams, and Post (1) has been used in which the albumin is precipitated by a three percent solution of sulfosalicylic acid and the resulting cloudiness is compared with a set of permanent standards. The results are reported in milligrams per 100 cc of urine.

In the beginning most of the urine samples were collected by waiting for the cow to urinate. The urine was caught in a dipper which was fastened to a stick 6 to 8 feet long. This arrangement made it possible to reach out and catch samples which might otherwise have been lost. Occasionally, because of lack of time, it was necessary to catheterize an animal.

During the last two years it was found possible to make most of the cows urinate rather quickly by the use of a method which was suggested by Smith and Little (2). This method is to rub with a blunt stick back and forth across the region immediately below the vulva.

Table 2. Occurrence of albuminuria in the Station herd. (N, tes

Cow No.	Breed	Date Born	1930	1931	1932	1933	1934	1935	19
E 29*	Jer.	12/22/23	N	NNN NNN	XX				
E 41	Jer.	9/16/25	X	N — —					
E 53	Jer.	11/20/26	X						
E 55	Jer.	12/ 4/26	X	NN					
E 68*	Jer.	9/17/27	X	— — —	— — —	— — —	— — —	— X X	X X X X X
E 70	Guern.	12/16/27	X	XN —					
E 77	Jer.	5/26/28	X	X N —					
E 81	Jer.	7/ 4/28	X	— — X					
E 100	Jer.	2/ 4/29	X	N — —					
E 102	Jer.	2/24/29	X	N — —	— —				
E 127	Jer.	12/14/29	X	— — —	— — —	—			
E 134	Jer.	1/22/30	X	— — —	— — —	— —			
E 135*	Jer.	2/ 1/30	X	— — —	X X				
E 138*	Jer.	3/28/30	X	— — —	— — —	— — —	— — —	— N	— X
E 139	Hol.	4/13/30	X	— — —	— — —	— — —	— — —	— N N	N N N X N N
E 140	Jer.	4/15/30	X	— — —	— X —	— — —	— — —	— N N	N N
E 142*	Jer.	5/31/30	—	— X —	— X —	— — —	X — —	—	
E 153	Jer.	11/12/30	X	X — —	— — —	— — —	— — —	— —	—
E 165*	Jer.	2/20/31		— —	— X X X	X X X	— — —	— —	— X X X X
E 167	Jer.	3/ 4/31		— —	— — N	X X X	N — —	— — —	— —
E 173	Hol.	4/20/31		— —	— N	N N X	X X —	— — —	— N N N N
E 176*	Jer.	5/25/31		— —	— N	X X X	X — —	— — —	— — X X X
E 180	Guern.	7/ 3/31		— —	— N N	N X N	N —		
E 182	Hol.	7/13/31		— —	— N N	X N X	X N —	— — —	— N N N N N N
E 186*	Jer.	8/ 3/31		— X	X X X	X X X	X — —	— — —	— N — X X
E 187	Jer.	9/28/31		— —	— N N	X N X	N — —	— — —	— — —
E 192*	Jer.	12/15/31			— X X	X X X	X X X	— — —	— X X X
E 193*	Jer.	12/21/31			— X X	N N N	N X X	X X —	— — —	— X X X X X X
E 194	Jer.	1/20/32			X N X	X X X	X X N	X N N	— — —	— N N N N N N
E 197	Jer.	2/10/32			N N	N N X	N X N	X X N	N N N	— — —	— N N N N N N
E 199	Jer.	2/22/32			N X	N X N	X N N	X N N	N N X	N	
E 200	Jer.	3/ 7/32			X	N N N	N N N	X N —	— — —	— —	— N N N N N X
E 212	Jer.	9/12/32				N	N X X	X X X	N N N	N N —	— — N N N N N N
E 215*	Jer.	10/ 1/32				X	X X X	X X X	X X —	—
E 218	Jer.	11/23/32				N	X X X	X X X	X N N	N — —	— — N N N N N N
E 223	Crossor a	1/ 7/33					N X N	X N N	X N N	N — —	— N — —
E 235	Hol.	5/26/33					X	— — X	N N N	N N —	— N — — — X N N N
E 237	Jer.	6/13/33						— — X	N N N	N N —	— N — — — N N N
E 238	Jer.	6/21/33						— — X	N N N	N N —	— N — — — N N N
E 242	Jer.	7/23/33						— X	N N N	N N —	— N — — — N N N
E 243*	Jer.	7/26/33						— X	X X X	X X —	— X X X X X X
E 244	Jer.	8/ 3/33						— X	N N N	N N —	— N N N N N N N
E 250	Jer.	8/21/33						— N	N N N	N N —	— N N N N N N N
E 252	Hol.	9/23/33						— X	N N N	X N —	— N — — — X N N
E 256*	Jer.	11/22/33						X	N X X	X X —	— X X X X X X
E 271	Jer.	4/ 5/34						X	N X —	— N X N N N N N
E 272	Jer.	5/17/34						X	N X —	— — —	— — N N
E 279	Jer.	6/23/34							X X —	— N —	— — N N N
E 293	Jer.	10/14/34							—	— N X	— N X N
E 326	Jer.	9/ 7/35									X N N N
E 346	Jer.	2/11/36									X X
E 367	Jer.	10/13/36									

* Diagnosed as nephritis.

min negative; X, albumin found; —, not tested.)

Notes
Apr. 1, 1932.
d Aug. 31, 1931. No postmortem.
Nov. 25, 1930. Metritis. No postmortem notes regarding kidneys.
to stock yards Feb. 18, 1931.
d June 6, 1936.
to stock yards June 17, 1931.
to stock yards June 17, 1931.
Dec. 9, 1931. Metritis. No postmortem notes regarding kidneys.
Nov. 11, 1931. Metritis. No postmortem notes regarding kidneys.
June 17, 1932. Non breeder.
Apr. 1, 1933. Difficult parturition. No postmortem notes regarding kidneys.
to stock yards June 7, 1933.
May 8, 1933.
d Oct. 31, 1935.
in herd. Apparently normal.
d Dec. 17, 1935. Non breeder. Urinary tract appeared normal.
Feb. 17, 1934.
for slaughter Nov. 21, 1934. Mastitis. No postmortem.
d March 18, 1936.
for breeder Apr. 12, 1935.
to beef herd for nurse cow May 20, 1936.
d March 18, 1936.
for slaughter June 7, 1933. Aborted.
in herd. Apparently normal.
d March 18, 1936. Suspicious to test for Bang's disease.
d Oct. 31. 1935. Non breeder.
d Oct. 31, 1935.
d June 13, 1935.
in herd. Apparently normal.
d Dec. 8, 1936. Unprofitable.
Sept. 7, 1934. Non breeder.
in herd. Apparently normal.
in herd. Apparently normal.
April 6, 1935.
in herd. Apparently normal.
Aug. 29, 1935.
in herd. Apparently normal.
in herd. Apparently normal.
d Nov. 6, 1936.
in herd. Apparently normal.
in herd.
in herd. Apparently normal.
d Nov. 3, 1936. Non breeder.
in herd. Apparently normal.
at clinic for experimental purposes.
in herd. Apparently normal.
May 28, 1936. Septicemia following calving.
in herd. Apparently normal.
in herd. Apparently normal.
in herd.
in herd.
in herd.

The occurrence of albuminuria in the herd is summarized in Table 2. This table includes all animals which have shown albumin in the urine more than once. An X indicates that one or more samples of urine showed albumin during the space of time covered by the symbol. A period of negative examinations is covered by an N. A dash (—) indicates a period during which no urine was examined. All cases in which a definite diagnosis of nephritis was made are indicated by an asterisk (*). These nephritis cases are discussed in the text. The amount of albumin found in the urine is not stated in this table but will be given in the case reports which follow.

Besides these animals recorded in table 2, four Jersey and four Holstein calves have shown albuminuria for short periods during the past two years. In four of these cases the albuminuria was accompanied by scours and in the other four it could not be explained. They are all normal at present.

The following case reports present the symptoms which may be of significance in explaining the development of the kidney condition.

CASE REPORTS

E 29. Born December 22, 1923. This was the first cow in which a definite diagnosis of nephritis was made. The health record which was started in 1928 gives no indication that there was anything wrong with her urinary tract prior to February, 1932. Four examinations of her urine in November, 1930, and one on November 19, 1931, showed no albumin. She developed severe mastitis on February 19, 1932. A sample of urine obtained on March 1, 1932, was bloody and showed a marked albuminuria. She died on April 1, 1932. The postmortem record includes the following: "Mastitis and nephritis with abscessed pyelitis and cystitis and with granulations on the bladder mucosa. Cultures showed a non hemolytic streptococcus."

E 68. Born September 17, 1927. This cow never showed any symptoms of nephritis. She produced five normal calves between April, 1930, and March, 1935. Her butter-fat production exceeded 300 pounds for each of these five lactations. She was killed on June 13, 1936, because of failure to breed.

The examination of her urine was carried out in two periods. Each of five samples taken during October and November, 1930, showed a trace of albumin. Repeated examinations made between May, 1935, and the time of her death all showed albumin which varied in amount from 40 to 150 mgm per 100 cc. No sample was ever negative to tests for albumin.

The kidneys appeared only slightly enlarged; the right one weighed 22 ounces and the left one 23 ounces. The capsule, which was thicker than normal, peeled readily showing the surface of the cortex to be covered with numerous small reddened areas. The surface was also slightly granular and showed several small cysts. These changes were uniformly distributed over the surface of each kidney.

On section, the most marked change was the increased thickness of the cortex and the thinness of the medulla. The cortex was so much swollen that the fissures between some of the lobules were not apparent. Its color was yellowish brown with an occasional reddened area on the cut surface. These areas were found in the outer part of the cortex. The medullary tissue was normal in color but was somewhat atrophied. No changes were found in the calyces, the ureters or the bladder. A careful examination of both kidneys revealed no evidence of calculi. Cultures from the cortex and calyces of both kidneys were negative.

E 135. Born February 1, 1930. This heifer evidently suffered with nephritis from calfhood to the time of her death on May 8, 1932. She was badly bloated on September 9, 1930, when only 7 months of age. From this date on the health record contains numerous references to treatments for chronic indigestion. Examinations of her urine during November and December, 1930, and again in February and March, 1932, all showed more or less albumin. On two occasions the albumin in the urine was reported as "marked."

She was found dead in the pasture. The postmortem notes report that kidneys "showed chronic interstitial nephritis of long standing." No histological study nor cultures were made.

E 138. Born March 28, 1930. This cow was killed on October 31, 1935, because of chronic mastitis which was first noted in October, 1933. Altho she showed no symptoms indicating an involvement of the urinary tract, traces of albumin were found in her urine during November and December, 1930, and again during October, 1935. One examination of her urine on May 19, 1935, showed no albumin. The kidneys appeared normal in every way except that each weighed only fifteen ounces. The calyces, ureters and bladder showed no changes. These kidneys were not cultured.

The microscopic changes were less marked in these kidneys than in the other cases. The principal changes noted were a cellular infiltration into the glomeruli, connective tissue formation in a few of the glomerular capsules, cloudy swelling of the epithelium of the convoluted tubules, and a slight edema around the tubules in the pelvis. There were a few small areas of round cell infiltration into the interstitial tissues of the cortex. The epithelium over the pelvis was normal. Both kidneys were equally affected.

E 142. Born May 31, 1930. This cow was treated for chronic indigestion from October, 1931, to the time of her death. On July 11, 1933, it was necessary to cut her vagina in order to deliver a calf. It was noted on October 31, 1933, that she was urinating frequently. A rectal examination showed her bladder to be very much enlarged and the wall thickened. She was treated for cystitis

by irrigating the bladder with disinfectants, from November 10, 1933, to January 4, 1934. Her urine was negative for albumin in October, 1931, but showed albumin in February and March, 1932, and again in August, 1933. She died on February 17, 1934. The postmortem report contains the following statement regarding the urinary tract: "Purulent nephritis, right kidney enlarged four times and filled with fistulous tracts. Cystitis." The kidneys were not cultured and no sections were made.

E 165. Born February 20, 1931. The clinical record is given in Table 3.

Table 3. Observations on Cow E 165.

Examination of Urine		Health Record	
Date	Albumin	Date*	Notes
1931		1931	
Oct. 6	None	Oct. 11	Off feed, treated for indigestion.
" 9	Present		
" 21	Marked	" 12	Treated for indigestion.
" 22	Present	" 18	Still off feed. She strains to urinate.
1932		" 21	Treated for indigestion.
Apr. 12	"	1932	
May 16	"	May 23	Bloated. Treated for indigestion.
June 14	None		
July 19	Trace	1933	
Sept. 15	"	July 2	Gave birth to dead 273-day calf.
Oct. 17	Present		
Nov. 14	"	1934	
Dec. 13	None	July 29	Normal parturition.
		1935	
1935		Jan. 10	Indigestion.
May 17	5 mg % **	Apr. 7	Indigestion. Slight attack of mastitis.
June 19	None		
Dec. 10	10 mg %	July 6	Normal parturition.
		Aug. 6	Treated for indigestion.
1936		1936	
Feb. 14	None	Mch. 10	Pregnant from 9/24/35 breeding.
Mch. 3	"		
" 16	50 mg %	" 18	Killed because unprofitable producer.

* In order to conserve space the dates under "Health Record" have been condensed so that they do not correspond with the dates under "Examination of Urine."

** Meaning 5 milligrams in 100 cubic centimeters.

The kidneys appeared normal on external examination, except that each weighed 15 ounces. The cut surface showed the medulla to be somewhat thickened and darker than normal. The ureters and bladder appeared normal. Both kidneys showed *Escherichia coli* in the cultures. The cultures from the ureters were negative.

The most noticeable changes in these kidneys was a distension of the tubules in the medulla. This was more marked in the pelvis where the distension had

resulted in the formation of small cysts. The cortex showed evidence of a glomerulonephritis. Many of the glomeruli were filled with round cells and were swollen so that they completely filled the capsule. All the tubular epithelium in the cortex showed a cloudy swelling.

The accompanying graph shows the production record of E 165 by weeks for three successive lactations. This record is fairly typical of the production

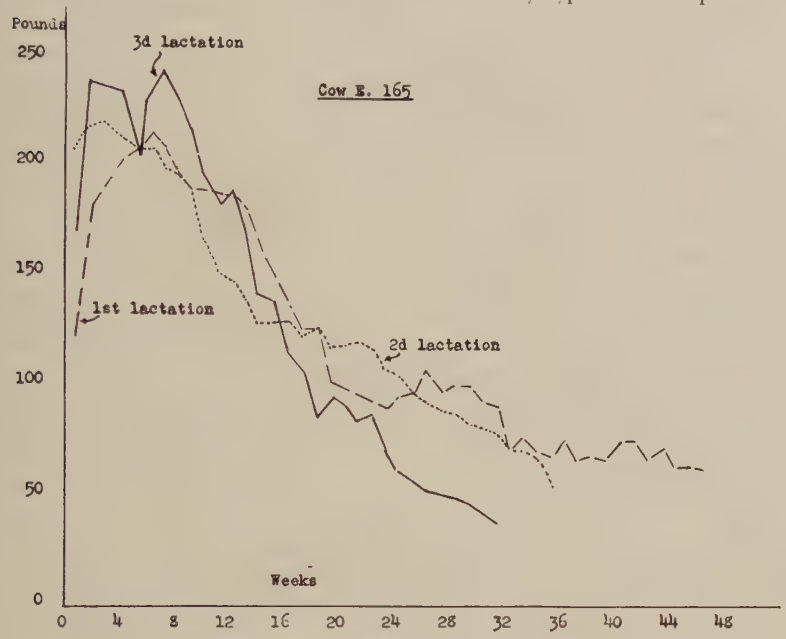

Figure 1. Production of milk, cow E 165.

made by the nephritis cases. While the weekly fluctuation is not so marked as in the case of E 243, which is discussed later, the failure to show characteristic increase in production due to advancing age should be noted.

E 176. Born May 25, 1931. The clinical record is given in Table 4.

Postmortem. Both kidneys very much enlarged; the right one weighed 36 ounces and the left one 48 ounces. The capsule was adherent. The bladder wall was very much thickened, with patches of exudate hanging to mucous membrane. Ureters enlarged to about twice normal size. Calyces of the kidneys contained a considerable amount of exudate and phosphatic material. The hemorrhage was confined to the bladder. Cultures from both ureters and kidneys showed a nonhemolytic streptococcus with an occasional colony of staphylococcus.

The histological examination of the kidneys showed large areas of fibrosis and round-cell infiltration extending from the capsule well down into the me-

dulla. Most of the glomeruli within these areas were fibrosed. Practically all those outside these areas had either undergone a pressure atrophy or were infiltrated with round cells. The glomerular capsules showed a thickening due to connective tissue formation. All the tubules were distended. In many of these tubules, especially in the medulla, the epithelium was completely sloughed off the basement membrane. There was considerable connective tissue formation around these tubules.

Table 4. Observations on Cow E 176.

Examination of Urine		Health Record	
Date	Albumin	Date*	Notes
1932		1932	
Apr. 12	Negative	Nov. 21	Treated for indigestion.
May 16	"	Dec. 1	Grunting, would not eat.
June 14	"	1933	
July 19	Trace	Aug. 19	Gave birth to normal calf. Difficult parturition. Necessary to cut vagina.
Sept. 15	"		
Oct. 17	"		
Nov. 14	Negative	1934	
Dec. 13	Trace	June 12 to 23	Mastitis.
1933		July 26	Normal parturition.
Feb. 20	"	1935	
		Mch. 28 to Apr. 24	Mastitis.
1935			
May 15	Negative	July 7	Normal parturition, followed by metritis.
Nov. 13	100 mg %		
" 14	70 " "	Sept. 4	Indigestion.
" 16	100 " "	Sept. 6	Mastitis.
" 19	40 " "	Nov. 11	Mastitis. Removed to clinic following this attack because udder practically ruined.
1936			
Feb. 17	100 " "		
" 24	100 " "		
Mch. 11	30 " "	Nov. 20	Losing in condition.
		1936	
		Feb. 16	Catheterized and obtained sample of bloody urine containing shreds of fibrin and fragments of phosphatic material.
		Feb. 18	Still passing fibrin and phosphatic material in urine.
		Mch. 11	Urine practically free from blood.
		" 16	Bloody cystitis.
		" 18	Killed.

* In order to conserve space the dates under "Health Record" have been condensed so that they do not correspond with the dates under "Examination of Urine."

E 186. Born August 3, 1931. The clinical record is given in Table 5.

Postmortem. Both kidneys appeared normal except that the right kidney weighed 20 ounces and the left one 13 ounces. Bladder wall slightly thickened but otherwise normal. Ureters normal in size. Cultures showed nonhemolytic streptococcus and *E. coli* in calyces of both kidneys. Cultures from cortex negative.

Table 5. Observations on Cow E 186.

Examination of Urine		Health Record	
Date	Albumin	Date*	Notes
1931		1931	
Nov. 19	None	Nov. 25	Coccidiosis and pneumonia.
" 26	Present	to 30	
1932		1932	
Feb. 18	Marked	Jan. 16	Off feed.
Mch. 1	Present	" 21	Indigestion.
Apr. 12	"	1933	
May 16	"	Aug. 21	Normal parturition.
June 14	Trace	1934	
July 19	"	Mch. 1	Diarrhea.
Sept. 15	Present	July 30	Normal parturition.
Nov. 14	Trace	1935	
Dec. 13	"	Apr. 21	Mastitis.
		Oct. 3	Suspicious to test for Bang's disease. Removed to clinic to freshen.
1933			
Feb. 20	Present		
		Nov. 5	Normal parturition.
1935		" 18	Acetonemia. Since this cow was a discard she was treated in an experimental way. She was catheterized frequently to get urine for analysis.
May 7	None		
Nov. 11	"		
" 21	100 mg %		
" 22	20 " "		
" 25	100 " "		
" 27	40 " "	" 25	Cystitis.
		1936	
1936		Mch. 18	Killed. Much improved in condition at time of death.
Mch. 16	10 " "		

* In order to conserve space the dates under "Health Record" have been condensed so that they do not correspond with the dates under "Examination of Urine."

The histological sections showed fibrosis which was more severe in the left kidney. Both kidneys showed a distension of the tubules in the medulla similar to that observed in E 165. Both kidneys showed evidence of an acute glomerulonephritis. The glomerular capsules showed little change. Sections from both kidneys showed areas of severe congestion of the capillaries around the tubules in the cortex. This was the only case in which this change was noted.

E 192. Born December 15, 1931. The clinical record is given in Table 6.

Postmortem. Owing to the recto-vaginal fistula the vagina contained quantities of feces. The bladder wall was much thickened. The mucous membrane was reddened and carried small patches of exudate. The right kidney weighed 13 ounces and the left one 17 ounces. The papillae of both kidneys were much

darker than normal and the calyces contained a small amount of exudate. The medullary tissue of the right kidney was somewhat thinner than normal. The cultures from both kidneys showed *Staphylococcus aureus* and a nonhemolytic streptococcus.

Table 6. Observations on Cow E 192.

Examination of Urine		Health Record	
Date	Albumin	Date*	Notes
1932		1932	
Mch. 30	Trace	Jan. 20	Diarrhea.
Apr. 29	Present	to	
May 30	Marked	Jan. 30	
July 5	Present	Apr. 15	Indigestion. Feces dry. Temperature 105.2.
Aug. 1	Trace		
Oct. 3	Present	May 30	Urinating rather frequently.
" 31	Marked	June 20	Off feed.
Dec. 6	Present	to	
1933		June 26	
Jan. 3	"	1933	
Feb. 16	"	Feb. 18	Coccidiosis.
Mch. 14	"	to	
Apr. 6	"	Feb. 28	
May 3	"	1934	
" 5	"	July 19	Difficult parturition. Necessary to cut vagina.
July 5	"		
Aug. 2	Trace	1935	
Oct. 3	None	Apr. 27	Mastitis.
Nov. 7	Trace	July 15	Large recto-vaginal fistula found.
Dec. 5	Present		
1935		Oct. 31	Killed. In poor condition at time of death.
May 15	5 mgm %		
July 15	None		
Oct. 15	5 mgm %		
" 21	5 " "		

* In order to conserve space the dates under "Health Record" have been condensed so that they do not correspond with the dates under "Examination of Urine."

The most marked microscopic changes were in the pelvis where numerous purulent foci were found underneath the epithelium of the calyx. The tubules of the pelvis showed much degeneration and desquamation of epithelium. There was considerable edema and some connective tissue formation between the tubules. The cortex showed a cloudy swelling of most of the tubular epithelium, some cellular infiltration into the glomeruli, and connective tissue formation in practically all the glomerular capsules. The changes found in these kidneys were indicative of an ascending infection.

E 193. Born December 21, 1931. The clinical record is given in Table 7.

Postmortem. Left kidney. See Figure 2. Weight 14 ounces. The capsule was thickened and adherent over most of the kidney. Nearly one half of the lobules were atrophied and presented a roughened, uneven surface. One of these lobules was cystic and the remainder contained soft, friable, grayish-yellow

Table 7. Observations on Cow E 193.

Examination of Urine		Health Record	
Date	Albumin	Date*	Notes
1932		1932	
Mch. 30	Trace	Jan. 15	Scours.
Apr. 29	"	to	
May 30	Present	Jan. 30	
July 5	None	May 30	Urinating frequently.
Aug. 1	"	1933	
Oct. 3	"	Feb. 18	Coccidiosis.
" 31	"	to	
Dec. 6	"	Mch. 14	
1933		" 14	Frequent urination.
Jan. 3	"	Apr. 6	Frequent urination.
Feb. 16	Trace	1934	
Mch. 14	Marked	Oct. 14	Normal parturition.
Apr. 6	Present	Dec. 15	Off feed.
May 3	Trace	1935	
June 5	Present	Feb. 4	Off feed.
July 5	"	" 7	Not eating well.
Aug. 2	Trace	" 24	Treated for indigestion.
Nov. 7	Present	Mch. 9	Removed from dairy herd because production low. Used for nurse cow in beef herd.
Dec. 5	Marked		
1934			
Jan. 16	Present		
Feb. 8	Marked	Sept. 10	Normal parturition.
Mch. 14	Present	Nov. 29	Given a dose of salts.
1935		Dec. 2	Reported sick. Had not been eating well for several days. Poor condition.
Dec. 3	50 mgm %		
" 10	15 " "		
1936		" 3	Slight improvement. Still urinating frequently. Stands with back arched.
Feb. 14	20 " "		
" 17	20 " "		
" 24	15 " "	1936	
		June 13	Killed. In fair condition at time of death.

* In order to conserve space the dates under "Health Record" have been condensed so that they do not correspond with the dates under "Examination of Urine."

calculi. In the figure these lobules occupy that part of the kidney below the line. The location of the calculi in relation to renal tissues is shown in Figure 1. It is evident that they have all formed in the calyces of the kidney. In the lobules which contain the larger calculi, pressure atrophy has caused fibrous tissue to replace most of the normal structures of the cortex and medulla. These changes can be seen in Figure 4 on page 105.

Right kidney. See Figure 3. Weight 20 ounces. The capsule was adherent to most of this kidney. Almost all of the lobules presented a roughened and irregular surface. Four small calculi were found in the calyces of this kidney. These calculi were similar to those found in the left kidney. The lobules which did not contain calculi had undergone some fibrosis.

The bladder wall was somewhat thickened. Both ureters appeared normal. The ureter in Figure 2 appears large because the surrounding tissues were not dissected away before it was photographed. No blood nor phosphatic debris

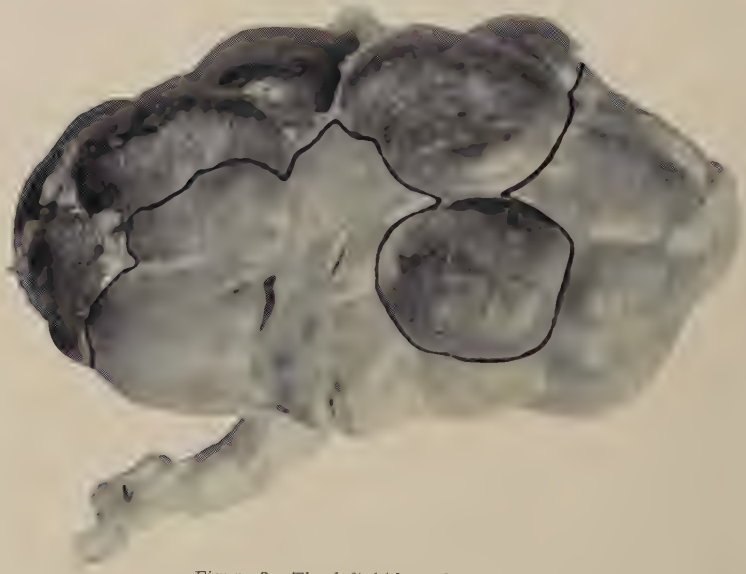

Figure 2. The left kidney from E 193.

Figure 3. The right kidney from E 193.

were found in the bladder or ureters. The cultures from the calyces and cortex of both kidneys were negative.

A histological study showed a diffuse fibrosis in both kidneys. This was more marked in the lobules which contained the calculi. In these, the calculi had caused a pressure atrophy of the medullary tissue and fibrous tissue had almost entirely replaced the functioning tissues of the cortex.

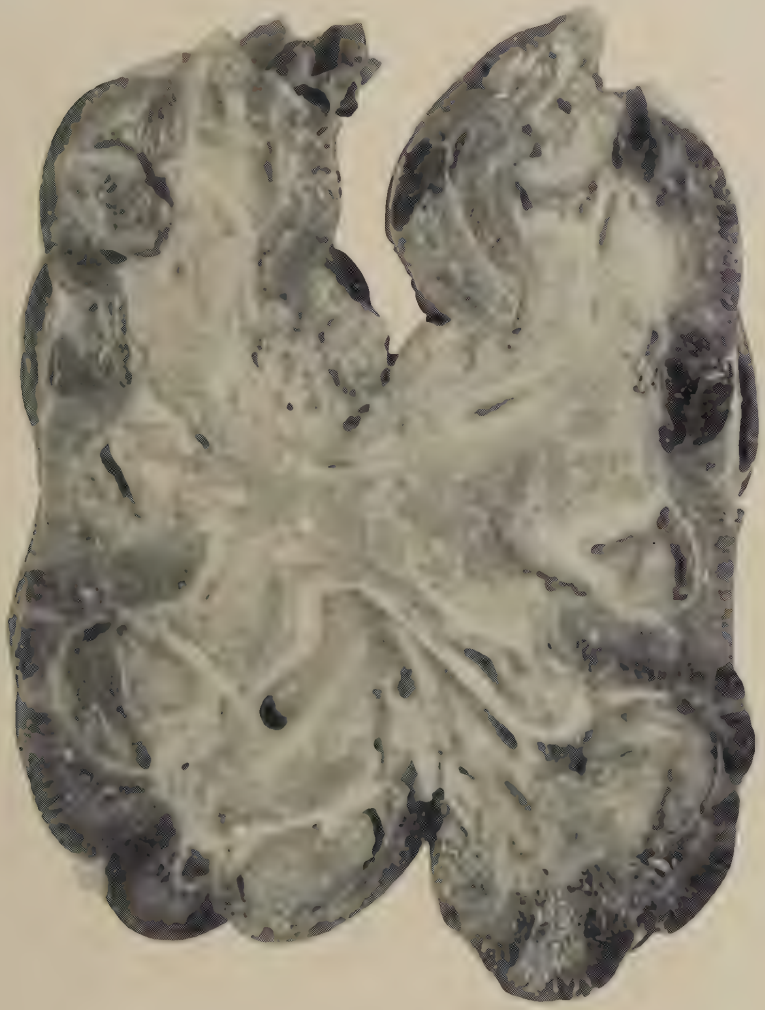

Figure 4. Section of left kidney from E 193 showing calculi and fibrous condition of the kidney.

E 215. Born October 1, 1932. The clinical record is given in Table 8.

Postmortem. The right kidney weighed only 10 ounces. The capsule was adherent over the entire kidney and the surface of the kidney was granular. Many of the lobules contained calculi similar to those found in the kidneys of cow E 193. The left kidney weighed 16 ounces. The lobulation of this kidney was not as apparent as it is normally. This was evidently due to the cortex being somewhat swollen. The capsule was adherent over the entire surface. No calculi were found in this kidney.

The bladder and ureters were apparently normal. A careful examination of them revealed no debris nor evidence of phosphatic material. Cultures from both kidneys revealed a nonhemolytic streptococcus.

The histological changes in these kidneys were similar to those found in E 193 except that the fibrosis was much more severe.

Table 8. Observations on Cow E 215.

Examination of Urine		Health Record	
Date	Albumin	Date*	Notes
1932		1932	
Oct. 31	None	Oct. 11	Scouring.
Dec. 6	Trace	" 31	Scouring.
1933		1933	
Jan. 3	"	Jan. 4	Scouring.
Feb. 16	None	Apr. 1	Constipated, bloated.
Mch. 14	"	May 4	Coccidiosis.
Apr. 6	Marked	1934	
May 3	Present	Jan. 7	Refused feed. Treated for indigestion.
June 8	Trace		
July 10	None	" 30	Treated for indigestion.
Aug. 8	"	Feb. 2	Treated for indigestion.
Oct. 3	Marked	" 20	Treated for indigestion.
Nov. 9	Present	Mch. 14	Treated for indigestion.
Dec. 5	None	" 15	Started use of formin for kidneys.
1934			
Jan. 11	Present	" 27	Bloated. Treated for indigestion.
Feb. 6	"		
Mch. 7	Marked	Dec. 19	Diagnosed pregnant.
Apr. 10	Present	1935	
May 8	"	Mch. 12	Aborted.
June 5	"	Apr. 6	Killed at clinic. Has been gradually losing in condition. She was found down and was drawn to clinic.
July 25	"		
Sept. 20	Marked		
1935			
Mch. 12	"		

* In order to conserve space the dates under "Health Record" have been condensed so that they do not correspond with the dates under "Examination of Urine."

Table 9. Cow E 243. Born July 26, 1933.

Date	Albumin	Condition and Treatment
1933		
Oct. 10	Present	
Nov. 14	"	
Dec. 12	Marked	
1934		
Jan. 6	Present	
" 31	—	Treated for indigestion.
Feb. 4	—	Treated for indigestion to February 20. Symptoms of colic.
" 8	Present	
Mch. 9	"	Indigestion.
" 14	"	
Apr. 12	"	
May 10	None	
June 7	Present	
July 23	None	
Sept. 20	Present	
1935		
Apr. 22	10 mg %	
Oct. 22	—	A normal parturition.
" 29	10 mg %	
Dec. 5	10 " "	
" 9	—	Off feed. Lying down most of the time. Seems to stretch when standing. Drinks very little water. Rumen contractions normal. Feces firm. Temperature 101.6. Pulse 62. Respiration 20. Gave only 2 lbs. milk in afternoon.
" 10	50 mg %	Eating better. 15 lbs. milk in morning. Passed about 2 ozs. of clotted blood. Blood and pus cells in urine.
" 11	50 " "	Eating well but not on full feed.
" 17	100 " "	Symptoms of colic in afternoon.
1936		
Jan. 23	—	Lying down stretched out behind most of the time. Kicks at abdomen when standing. Voided about 2 cc. of a dark, cloudy urine. Pulse so fast and weak unable to count it. Temperature 98.4. Catheterized in order to irrigate bladder. Bladder so much in spasm that it was difficult to introduce 300 cc. of a warm physiological saline. Returning fluid contained fragments of phosphatic material. Started treatment with 4 ozs. cod liver oil per day.
" 24	—	Cow shivering during forenoon. Drank only 4 qts. water between 7:00 a. m. and noon. Chewing cud at noon. Pulse 60. Temperature 100.

Table 9 (Continued)

Date	Albumin	Condition and Treatment
Jan. 25	200 mg %	Still shivering. Pulse 60. Temperature 101.0. Catheterized and obtained reddish-brown urine which contained blood cells and fragments of phosphatic material. Washed bladder with physiological saline.
" 28	30 " "	Not as much sediment in urine.
" 30	30 " "	More colicky pains.
Feb. 3	—	Urinating frequently.
" 15	40 mg %	Passed a mass of fibrin in urine 3 inches in diameter and ⅛ inch thick which contained fragments of phosphatic material.
" 16	—	Discontinued cod liver oil.
" 25	50 mg %	Exhibiting symptoms similar to those observed on January 23. Temperature 100.5. Pulse 80 and weak. Respiration 33. Started the use of cod liver oil again.
" 26	15 " "	8:00 a. m. Still in pain. Temperature 100.2. Pulse 90. Respiration 17. 3:00 p. m. In less pain but is kicking at abdomen occasionally. Has urinated and defecated only a small amount. Has taken no water since 8:00 a. m. Voided a liter of urine at 3:30 p. m. Pulse 72. Temperature 101.3.
" 27	15 " "	8:30 a. m. Appears better. Pulse 60. Temperature 100.8. Has taken 5 gal. of water since 3:30 yesterday. Sediment from centrifuged sample shows large amount of streptococcus or staphylococcus and pus cells.
Mch. 4	50 " "	Losing flesh. Not eating well. Producing only 11 lbs. milk per day. Small masses of fibrin and fragments of phosphatic material in urine.
" 6	50 " "	Passed small clot of blood in urine.
" 17	—	Mass of fibrin containing fragments of phosphatic material found behind her in stall.
" 30	15 mg %	
Apr. 1	10 " "	
May 3	—	Off feed to May 5. Production lowered.
June 22	—	Much improved. Cod liver oil dosage decreased to 2 ozs. per day.
Aug. 6	10 mg %	Still improving. Urine still very cloudy with pus cells.
Oct. 13	—	First lactation terminated.

Table 9 (Concluded)

Date	Albumin	Condition and Treatment
Oct. 29	5 mg %	
Dec. 7	5 " "	
" 11	5 " "	Placed on ration made up entirely of oats, corn and bran, which furnishes less protein than her usual ration. She was also given 100 gms. of sodium acid phosphate and 8 gms. of formin per day.
" 12	—	A few shreds of fibrin in urine.
" 14	30 mg %	
" 15	20 " "	
" 16	20 " "	More fibrin in urine, but no evidence of phosphatic material. Pus cells in urine increased. Culture from urine showed a nonhemolytic streptococcus and a few staphylococci.
" 19	20 " "	
" 20	—	Discontinued the treatment because cow is within about 3 weeks of parturition. Resumed her usual ration. It was possible to lower pH of urine from 7.8 to 5.8 but kidney condition showed no improvement.
" 23	10 mg %	
1937		
Jan. 4	15 " "	
" 9	15 " "	
" 14	—	Second calf born. A normal parturition.
" 29	5 mg %	
Feb. 24	10 " "	
Mch. 15	10 " "	
Apr. 15	20 " "	Not eating well.
" 16		Appeared normal.
" 28	10 " "	

E 256. Born November 22, 1933. This animal showed a trace of albumin in her urine at three weeks of age. Tests on January 4 and February 6, 1934, were negative. All samples of urine examined since have shown more or less albumin. Except an intestinal upset during the winter and early spring of 1934, she has had no serious sickness. She has always appeared unthrifty and has always been a non breeder. At present, she is being kept at the clinic as an experimental animal.

The following animals are of interest because of their tendency to show traces of albumin in their urine at frequent intervals since shortly after birth. A consideration of the histories of some of the animals which have been discussed indicates that perhaps these heifers may be the next ones to develop nephritis.

E 326. Born September 7, 1935. This heifer showed traces of albumin in her urine during October, 1935, September, 1936, and again on January 22, 1937. Outside of this, she has been normal in every respect.

E 346. Born February 11, 1936. Twenty-three examinations of this heifer's urine, made between February 21, 1936, and June 18, 1936, all showed albumin in amounts varying from a slight trace up to 40 mg. per 100 cc. This albuminuria disappeared from August 6, 1936, to April 2, 1937, when 5 mg per 100 cc was found. Two more examinations during the month of April showed the same amount of albumin. This calf has been normal thruout the entire period.

E 367. Born October 13, 1936. Examinations of her urine showed 5 mg of albumin per 100 cc on October 28 and 30, 1936, and 10 mg on December 10, 1936, and March 5, 1937. All other examinations were negative. She was treated for scours on October 21 and December 10, 1936. Outside of this, she has appeared normal.

SYMPTOMS

The case reports give a brief account of the symptoms observed in the condition under investigation. In studying them, it should be kept in mind that only four of these animals remained in the herd until the kidney condition brought on death. Some of the cases were disposed of early in the course of the disease because of other troubles. A few of this later group had exhibited only a few attacks of "indigestion" at the time of disposal.

The recurrent attacks of "indigestion" are the most constant symptoms noted in these cases. The attacks varied in intensity from a partial loss of appetite to the severe renal colic shown by E 243. While we cannot be sure that these symptoms of indigestion are due to the kidney condition, the fact remains that they were noted more often in the nephritis cases than in the other animals.

The most pronounced of the other symptoms were seen in the cows in which cystitis developed. These showed the frequent passing of small quantities of bloody urine which contained clots of exudate, pus and fragments of phosphatic material. They all suffered severe colicky pains and lost condition rapidly during these attacks. Marked improvement was noted in the condition of the animals as the cystitis cleared up.

All the advanced cases urinated more frequently than the normal animals. This symptom was more noticeable in the cows suffering with cystitis but was also noted in the other cases. The urine was usually almost colorless and in most cases the specific gravity was low.

The urine from cows with infected kidneys is usually cloudy because of a suspension of pus cells. This type of cloudiness can be easily detected because it does not settle out as rapidly as a suspension of carbonates or phosphates. It is not uncommon to find pus cells still in suspension after the urine has stood over night.

Albuminuria. This study has shown that albumin may occasionally occur in the urine of cattle in which there is no serious involvement of the urinary tract. It is common knowledge that a transitory albuminuria may accompany many febrile diseases. In this work, it has been found accompanying mastitis, metritis, pneumonia, enteritis and coccidiosis.

It is not uncommon to find an occasional animal which, without any apparent cause, shows varying amounts of albumin in the urine for certain periods of time. Sjollema (3) mentions the occasional occurrence of a feeble protein reaction in the urine of normal cattle, seen more often in the autumn while the cows were still on grass. Stewart (4) reports the periodic occurrence of a rather marked albuminuria in sheep. His postmortem findings and a study of the diet of these sheep left him unable to explain the condition satisfactorily. Similar findings have been made in this herd. Several cows and heifers have shown a rather marked albuminuria when there was nothing in their clinical history to explain its appearance. Daily examinations of the urine from these animals often showed that the albuminuria cleared up spontaneously within a few days. Many of these cows have shown no further albumin in their urine.

It will be noted by examining Table 2 that albuminuria was observed early in the life of most of the cows which later developed nephritis. Nine of the eleven cases, with a clinical record complete from birth, began to show it from three months to one year of age. It is difficult to explain this early appearance of a persistent albuminuria. With cows E 142, E 165, E 186, E 192, E 193, and E 215 the initial appearance of albumin was preceded by an attack of either enteritis, indigestion or coccidiosis. A study of the health record of this herd shows, however, that many of the calves and heifers suffered similar attacks with no permanent injury to the kidneys. The clinical record of the rest of these cases offers nothing which might explain the onset of albuminuria.

In this connection, attention should again be called to the rec-

ord of E 346. Albumin was found in her urine ten days after birth. Following this, albumin occurred in traces for a period of four months, after which all tests for albumin were negative for nine months. As far as can be determined, she has been normal in other ways since birth and yet traces of albumin have again appeared in her urine. It is hoped that further study of her case will offer help in explaining this condition.

E 68 offers another interesting case for study in this connection. Unfortunately, no examinations were made of her urine from 1931 thru 1934. It is significant, however, that all samples examined in 1930 and during 1935 and 1936 showed various amounts of albumin. While four cultures of her upper urinary tract were negative, her kidneys showed changes suggesting a chronic nephritis of long standing. The microscopic examination showed a marked chronic glomerulonephritis with considerable hyalin in the glomerular tufts, a fibrous thickening of practically all Bowman's capsules, large areas of round-cell infiltration and fibrosis in the cortex, and a profuse degeneration of the tubular epithelium. In spite of these findings, a study of her clinical history and of her daily milk weights for five lactations gives no indication of any sickness.

The records show that all the cases except E 29 have shown albuminuria more or less regularly from early life, up to the time of death or disposal. In some of them the amount of albumin was increased as a result of some infectious process. Infection was found in six of the eight urinary tracts which were cultured. The two which were negative to culture showed changes which indicated that they might have been infected at one time or another. It is impossible to determine the source of the infection which has affected the kidneys. The possibility has been considered that the use of the catheter may be blamed for some of it. While it would be unwise to say that this has not happened, the fact remains that the catheter was used on Jersey and Holstein alike and that none of the Holsteins have shown nephritis. In three of the cases, it was necessary to cut the vagina in order to deliver the first calf because of an abnormality of the vaginal wall. While this may have been the direct cause of the infection in the urinary tract, all these cows had shown albuminuria for some time before the operation.

The early appearance of persistent albuminuria which tends to increase in severity, the frequent occurrence of symptoms of nephritis following infectious conditions, and the postmortem findings in these cases all suggest that this condition may have started as a sort of functional albuminuria or nephrosis which gradually weakened the kidneys to the point where they offered little resistance to infection. Such a functional albuminuria is observed occasionally in human medicine. Burden (5), in an analysis of 58 cases of what he terms an idiopathic or persistent functional albuminuria, suggests that this condition may lead to further damage to the urinary tract. In this connection, he states, "We cannot help wondering whether these repeated functional disturbances may not in time lead to organic changes in the kidney, heart and blood vessels." A study of the occurrence of albuminuria and nephritis in respect to the breeds affected adds some weight to this theory. Table 2 shows that, out of the sixty animals which have shown albuminuria more than once, 80 percent were Jerseys. None of the nine Holsteins showed the persistent type of albuminuria. An analysis of all the cows examined during the past six years is presented in Table 10.

Table 10. A synopsis of the records of all animals examined from October 29, 1930, to March 5, 1937.

	Jersey	Holstein	Guernsey
Number examined	103	45	8
Percentage showing no albuminuria	30	53	50
Percentage showing albuminuria one or more times	70*	47	50
Number definitely diagnosed as nephritis	13	0	0

* Including Jersey-Guernsey crossbred.

This shows that, while nearly half of the Holsteins examined showed albumin in their urine at one time or another, not one of them developed nephritis. Seventy percent of the Jerseys examined had albumin in their urine and nephritis was diagnosed in thirteen of these. When we consider that the cows of both these breeds were maintained in the same manner as regards feeding, management and treatment of diseases, these findings are rather striking. It is barely possible that we are working with a strain of Jerseys which are more susceptible to various conditions which may affect the kidneys.

A study of the pedigrees shows that the twelve Jersey females which showed albuminuria followed by nephritis were quite closely related. Nine of the twelve were by one sire. Six were as much as 31 percent related to a sire 3 to 5 generations removed. Three others had a relationship coefficient of 21 to 25 percent to this same sire, and the remaining three from 9 to 13 percent. Nine of the twelve females were definitely inbred, having coefficients of inbreeding ranging from 1 to 10 percent. Two of the three having inbreeding coefficients of 10 percent were full sisters and the third carried 75 percent of the same blood.

THE CALCULI

The calculi which were found in the kidneys of E 193 are shown in Figure 5. Similar calculi were found in the calyces of the kidneys of E 215. No calculi nor phosphatic material were found in the ureters or bladders of these cows. Granular phosphatic material, which appeared like fragments from this type of calculus, was found at various times in the urine from E 176 and E 243. While exudate mixed with some of this granular material was found in the calyces of the kidney and in the bladder of E 176, there was no evidence of the formation of calculi anywhere in the urinary tract.

Buckner and Good (6) reported an analysis of what was evidently this same type of calculus, from the kidneys and bladder of a young Hereford bull which was reared on the Experiment Station Farm. They found them to be composed mainly of magnesium phosphate with a little calcium phosphate.

A preliminary examination of the calculi from E 193 showed them to be phosphatic with a small amount of fibrin and a slight trace of carbonate. A more complete analysis, made by the Chemistry Department, gave the following results:

Analysis of the material after drying at 100° C.

	Percent
Total nitrogen	1.67
Ammonia nitrogen	0.47
Cystine	none
Inorganic sulfate	trace
Total ash	74.8
Phosphorus	18.05
Magnesium	18.02
Calcium	1.22

These findings suggest that the calculi were composed largely of magnesium phosphate and magnesium ammonium phosphate, with a small amount of tricalcium phosphate, and about 20 percent of organic matter.

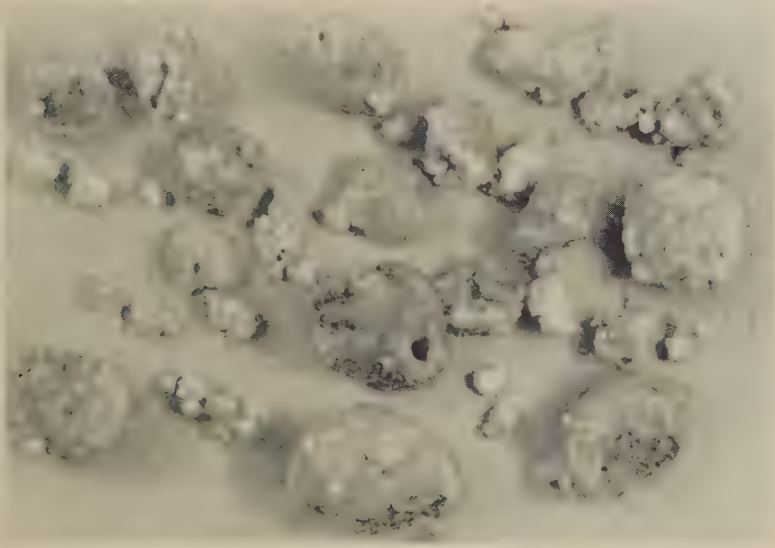

Figure 5. The calculi from the kidneys of E 193. Two-thirds natural size.

There are numerous references in the literature regarding the experimental production of phosphatic urinary calculi in rats by feeding a diet which is low in vitamin A. Higgins (7) reports the disappearance of these experimentally produced calculi from the urinary tract of the rats following the feeding of cod liver oil and an acid-producing diet.

While it is doubtful if any of these cows have suffered from a vitamin A deficiency, it was decided to try the effect of cod liver oil on E 243 after it was discovered that she was passing phosphatic material in her urine. The oil was given at the rate of 4 ounces per day from January 23 to June 22, 1936. Since that date she has had 2 ounces per day. Her case report and the record of her milk production both indicate that she has shown much improvement since the treatment was started. She is not completely recovered, however. A culture of her urine on December 16, 1936, showed a

nonhemolytic streptococcus and a staphylococcus. Her urine still shows many pus cells and is carrying a small amount of albumin. Except the administration of cod liver oil, this cow is being handled the same as the rest of the herd.

Figure 6. Production of milk, cow E 243.

The record of this cow's weekly production of milk is given in Figure 6. Her first lactation shows the wide fluctuations in production which were noted in the more severe cases of nephritis. It is doubtful if stopping the cod liver oil was in any way responsible for the second severe slump in production in her first lactation. Her second lactation shows a marked improvement over the first one with the weekly variation in milk production much less.

EXAMINATION OF THE URINE

The periodic examination of the urine was a valuable aid in dealing with this outbreak of nephritis. It is not a difficult procedure. By using the method described earlier in this bulletin it is

possible to collect the samples rather rapidly. If any difficulty is experienced in using this method, it will be well to try it first on the young calves. It is very easy to make them urinate in this way. Where it does not work with the heifers and older cows our practice has been to fasten them in the stanchions and wait for them to urinate, catching the samples with the long-handled dipper.

Allowing the samples of urine to stand over night in an ice box before testing them gives the phosphates, carbonates and fecal matter a chance to settle out. By carefully examining these samples in the morning suspensions of pus cells may be detected. If the sediment in the bottom of the bottle is not disturbed, a clear 10 cc sample may usually be drawn off the top with a pipette. If a clear sample cannot be obtained by this method the urine should be filtered. The sample may be tested for albumin by the heat and acetic acid method. This consists in heating the urine to boiling in a test tube and then adding a dilute acetic acid until the sample is acid. Where phosphates and carbonates are present it is necessary to contine the addition of acid until they are all dissolved. If the original sample was clear, any cloudiness noted after this treatment indicates the presence of albumin. It is a good plan, however, to examine other samples from positive cases in order to make sure of the diagnosis. Our experience has shown that the albuminuria may disappear after a few days. This examination of the urine has been of sufficient help in dealing with this condition to make us feel that it is an important procedure when working with nephritis in a valuable herd.

Our method of dealing with it was to diagnose the condition by the appearance of albuminuria and chronic indigestion and to dispose of cows that showed these symptoms as soon as their production did not warrant keeping them. All efforts to treat these cases with urinary disinfectants proved unsuccessful. At present, E 243 is the only case of nephritis left in the herd.

SUMMARY

1. Samples of urine from the cows of the Kentucky Experiment Station dairy herd were examined for albumin for a period of over six years. During this time 103 Jerseys, 45 Holsteins, and 8 Guernseys were under observation.

2. Some of the Jerseys showed albuminuria more or less regularly since calfhood and 13 of them finally developed nephritis. While some animals of the other breeds showed albumin in the urine, it did not appear regularly and they developed no nephritis.

3. The kidneys from these nephritis cases showed a wide variety of lesions and the cultures showed either a colon organism, a non-hemolytic streptococcus, a staphylococcus or a combination of these organisms.

4. The history of these cases, the variety of lesions found and the different types of organisms occurring in the urinary tract, all indicate that this nephritis was not caused by a specific infection.

5. The possibility is suggested that we are working with a strain of Jerseys which is susceptible to conditions affecting the urinary tract. A study of the pedigree of these afflicted animals strengthens this argument.

6. A favorable report is given regarding the use of cod liver oil on one case of nephritis.

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LEGUMES IN CROPPING SYSTEMS

BULLETIN NO. 374

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(119)

BULLETIN NO. 374

Legumes in Cropping Systems

By GEORGE ROBERTS*

INTRODUCTION

Farmers generally know that legumes perform an important function in the maintenance of fertility, but how to apply to best advantage what is known about them is not generally understood or practiced.

A great many people believe that the growing of legumes increases or maintains the productivity of any soil for non-leguminous crops, even tho the legume crop is harvested and no manure made from feeding it is returned to the soil. Under certain conditions with certain legumes, this is true. For example, a soil rich in mineral nutrients, in which nitrogen has been reduced to a low level, may gain considerable nitrogen from the stubble and large root system of legumes like red clover and biennial sweet clover. These crops also make considerable growth the year of seeding that is usually left on the land or grazed. Also, in the case of red clover, there is often considerable growth after the main crop is harvested that is often grazed or left on the ground. The roots of these plants weigh from one-third to one-half as much as the tops, while the percentage of nitrogen in the roots is more than four fifths as great as in the tops. In contrast with red clover and sweet clover are soybeans and cowpeas—annual legumes whose roots weigh only about one-sixth as much as the tops, while the percentage of nitrogen in the roots is only about two-thirds as great as in the tops.

* The experimental results used in this bulletin are taken from work conducted by various members of the Department of Agronomy, without attempting to indicate specifically the work done by each member. Practically all members of the staff in soils and crops have participated in it.

It is well established that legumes, even tho inoculated, fix nitrogen from the air only to the extent that the soil supply is insufficient for their needs.[1] Since this is true, the roots and stubble of legumes with large root systems such as red clover and sweet clover, may add nitrogen to soil of low or medium nitrogen content, notwithstanding that the crop is removed. Such legumes as cowpeas and soybeans, however, with small root systems and a smaller percentage of nitrogen in the roots than in the tops, could do this only where the nitrogen content of the soil is very low. This statement is supported by experimental results given in Tables 1 and 2. Soybeans and cowpeas can, of course, be used to increase nitrogen in the soil by turning them under, hogging them down, returning the straw when threshed, or returning the manure made by feeding them, and properly protecting the soil with cover crops. Obviously, the best legumes, when harvested, can maintain nitrogen in most soils only at a moderate level, while such legumes as cowpeas and soybeans, when harvested, deplete the nitrogen supply, unless the soil is very low in nitrogen, probably too unproductive for profitable use. Even on such soil, soybeans and cowpeas so handled cannot increase the nitrogen content very much.

It is quite certain that large losses of nitrogen from leaching often occur when cowpeas and soybeans are hogged down or turned under and followed by a cover crop, for the reason that the usual winter cover crop of grain does not make enough growth to utilize the available nitrogen. The tops and roots of a crop of soybeans yielding a ton of hay contain nearly 60 pounds of nitrogen, while the growth of a cover crop of grain seeded at the usual time contains about 10 to 20 pounds of nitrogen per acre at the end of the fall growing season, which is very likely not as much soluble nitrogen as usually develops in the soil under these conditions before growing weather ceases.

[1] New Jersey Agr. Exp. Sta. Bul. 436. The relation of soil nitrogen to nodule development and fixation of nitrogen by certain legumes. G. Giobel. 1926.

Early seeding of the cover crop would increase the nitrogen saved from leaching.

The annual lespedezas are legumes from which large losses of nitrogen may occur. As they mature before growing weather is over, available nitrogen subsequently develops, much of which may be lost by leaching unless something is seeded with them that will remain green thruout the winter and start growth early the next spring, for these lespedezas do not make very much spring growth until rather late. All annual lespedezas should either have a perennial grass seeded with them or the land should be seeded to a winter grain as early in the fall as is practicable. The ground can usually be sufficiently prepared for seeding by disking. If proper care is used in harvesting or pasturing lespedeza, usually enough seed is left on the ground for a stand the next spring.

An influence on nitrogen fixation by legumes that is not fully understood and that may be of far greater importance than is commonly believed, is the effect of growing a perennial or biennial grass with the legume, altho the associated legume may be a biennial or perennial. It is possible that the grass competing for soil nitrogen may force the legume to take a greater part of its supply from the air than if no grass were present. Also, the grass may prevent considerable leaching of nitrogen under a biennial or perennial legume that may take place when the legume is grown alone. Unpublished data from lysimeter experiments at the Kentucky Agricultural Experiment Station indicate that quite large losses of nitrogen by leaching may occur under some conditions with white clover and second-year red clover sods when grown alone, but that they are largely prevented when bluegrass is grown with them. Even alfalfa showed some loss, which was largely prevented by growing bluegrass with it. Another advantage of a combination of grass and legumes is that, grown upon a soil well supplied with mineral nutrients, the grass may be brought up to a protein content equal to that of the legume. Data from some of our nitrogen fixation studies have shown this to be true under certain conditions.

A vigorous sod of grass and legumes may supply the most favorable form of nitrogen for the production of tobacco. It has long been recognized by growers of Burley tobacco that the ideal soil condition for producing a high yield and quality of tobacco is a vigorous bluegrass sod on well-drained land. The vigorous sod of course depends upon a plentiful supply of nitrogen, which means a large amount in the vegetation turned under. The growth of tobacco on such land seems to indicate that nitrogen is converted into available form as needed by the crop. Conceivably there is a very great advantage in having the nitrogen in this form, for weather conditions that favor good growth of the crops favor nitrification and, conversely, weather conditions that slow up the growth of crops slow up nitrification; consequently available nitrogen is developed as needed.

When one undertakes to supply nitrogen in readily available form, the proper amount to apply cannot be determined, because weather conditions cannot be predicted. Too much may overdevelop the crop, set up a larger demand for moisture than is available, and cause a lower yield than if the nitrogen had not been applied. It may be possible, by a number of small applications, to avoid this difficulty. A single small application of soluble nitrogen at planting time may decrease the yield, particularly of corn, by stimulating early growth and setting up a larger requirement for water and nitrogen than can later be met, because of drouth or lack of soil nitrogen.

Tobacco growers on the sandy soils of the flue-cured–tobacco area recognize the critical importance of the nitrogen supply for the crop and use a mixture of readily available inorganic nitrogen materials, like nitrate of soda, and such organic nitrogen materials as dried blood and cotton seed meal, which later become available upon nitrification. May not nature's way, as manifested in a vigorous grass and legume sod, be the best way to supply most of the nitrogen to crops, to be supplemented, if necessary, by readily available nitrogen applied when symptoms indicate the need?

Another important relation of legumes to the maintenance

of productivity, that is often overlooked is that they make a very heavy draft upon the mineral nutrients of the soil, particularly calcium (lime), potassium and phosphorus. If the manure from feeding the legumes is not returned or if fertilizers and lime are not used, serious deficiencies in mineral nutrients may occur. For example, a ton of alfalfa hay contains about 5 pounds of phosphorus and 35 to 40 pounds of potassium, whereas the grain and stalk of a 50-bushel corn crop contains 10 to 12 pounds of phosphorus and about 35 pounds of potassium. Alfalfa, after the first cutting of the season, has only about five weeks in which to get its supply of these nutrients, whereas a corn crop has much longer. A potassium deficiency may develop for alfalfa long before it shows on corn and other crops harvested once a year. A five-year stand of alfalfa yielding 3 tons a year is more exhaustive of potassium than corn grown continuously on the land for fifteen years, yielding 50 bushels per acre per year. Five hundred pounds of superphosphate per acre for alfalfa is only 33 pounds per ton of alfalfa of the above length of stand and yield. No one would think of fertilizing corn, or any other crop of one yield per year, so lightly as 33 pounds of superphosphate per acre.

A top-dressing test was made at the Western Kentucky Substation beginning in the spring of 1931, on four- and five-year-old alfalfa that had been limed at the rate of 2½ tons of limestone per acre and fertilized with superphosphate at the rate of 400 pounds per acre, when sown. Three or more cuttings of hay had been removed each year after the year of seeding, and the alfalfa had begun to thin out. The tests consisted in top-dressing (1) with 500 pounds of superphosphate per acre, (2) with 500 pounds of superphosphate and 200 pounds of muriate of potash, compared with a check without top-dressing. The tests were made in quadruplicate and located in two fields. Only one application of fertilizers was used in the three years of the test, and nine cuttings were made. The total yield for all cuttings of alfalfa not top-dressed was 15,012 pounds per acre. Phosphate top-dressing increased this yield by 6480 pounds, while potash in the top-dressing further increased the yield by

618 pounds. About half of the total increase for phosphate was in the first year. This soil is quite low in phosphorus, but rather high in potassium.

It sometimes happens that tobacco grown on land that has been in alfalfa for several years is injured by potassium starvation, caused by the heavy draft alfalfa has made upon this element.

Some soils which have been made productive by the use of lime and phosphate and the growing of legumes will sooner or later become deficient in potassium, even for such crops as corn and wheat, unless manure is carefully saved and returned to the land. In fact, the increase in yield due to the lime, phosphate and legume treatment hastens the depletion of potassium and other elements.

REVIEW OF DISCONTINUED EXPERIMENTS PREVIOUSLY REPORTED

Legumes in Continuous Culture and Rotation. The value of legumes planted in corn at the last cultivation, under Kentucky conditions, is not so great as has generally been believed, because moisture conditions are such that good stands and good growth are difficult to obtain. Particularly is it difficult to get a stand of crimson clover, because the seeds germinate so quickly that a light rain causes them to sprout, after which they perish when the soil dries out around them.

Beginning in 1911, two plots of continuous corn were used in an experiment on the Experiment Station farm at Lexington to test the effect of legumes planted at the last cultivation of the corn (see Bulletin 331). The test was continued thru 1923. The yields of corn on the two plots the first year (a dry one), were 25.7 bushels and 24.7 bushels. A legume catch crop was seeded on the second plot each year thereafter. A winter cover crop of grain was used, except when crimson clover was the legume catch crop, and the cornstalks were left on the ground, beginning with 1915. Various legumes were tried. Cowpeas were seeded six years; crimson clover was used once after cowpeas failed, and twice as the only seeding. Once the

plot was divided equally between crimson clover and cowpeas, and once between cowpeas and soybeans. Vetch was used once. The average yield of corn for 1912-22 on the legume plot was 32.6 bushels, and 29.7 on the non-legume plot—not enough difference to pay for seed and labor in planting the catch crops.

The legume plot was limed in 1923 before planting corn. The yields of the two plots for that year were 48.2 bushels and 30.2 bushels, respectively, for the limed legume plot and the non-legume plot. Wheat was sown on them in the fall of 1923, and the following spring they were seeded to a mixture of sweet clover, red clover, and alsike clover. Sweet clover persisted on the limed plot only. The yields of hay were 5340 pounds and 4500 pounds, respectively. Corn followed in 1926, with yields of 62.9 bushels and 63.8 bushels, as compared with 74.9 bushels and 76.1 bushels on the limed and unlimed plots in the adjacent three-year rotation of corn, wheat and clover mentioned in the next paragraph. Thus one legume crop in rotation restored the land to comparatively high productivity for corn. Corn grown on unfertilized land nearby, that had been in continuous culture since 1920 yielded 33.6 bushels in 1926, but had yielded 70 bushels in 1920.

At the same time, on plots near the continuous culture plots, a three-year rotation of corn, wheat and clover was started in which cornstalks and wheat straw were returned, beginning in 1915. The yield of the first corn crop (1911) was 32.1 bushels per acre. The average yield for 1912–22 was 54.8 bushels, compared with 32.6 bushels on the continuous corn plot with a legume catch crop.

Nearby, on another set of plots, a four-year rotation of corn, soybeans, wheat and clover was started at the same time. No manure or crop residues were returned. The yield of corn was 30.7 bushels in 1911. For 1912–22 the average yield was 54.4 bushels.

In another test of corn in continuous culture, started in 1920 on the Experiment Station farm at Lexington, the yield of corn the first year was 64.9 bushels on a plot on which a legume was not used, and 67.7 bushels on an adjoining plot on

which cowpeas were seeded each year thereafter. The experiment was continued thru 1931. The average yield of corn for ten crops (exclusive of the first one and a failure in 1930 because of drouth) was 26.7 bushels on the non-legume plot and 34.4 bushels on the plot with cowpeas as a catch crop—a difference of 7.7 bushels. The cornstalks were removed and a winter cover crop of rye was used on both plots.

On a set of three plots adjacent to the foregoing experiments, a rotation of corn, wheat and clover was started at the same time. The average yield of corn for the first three years in this rotation, on unmanured land, was 41.9 bushels, compared with 44.5 bushels on the legume plot just mentioned, in continuous corn culture. The average yield of corn for ten years, 1921–31 (except crop failure of 1930), in rotation, was 51 bushels, as against 34.4 bushels on the legume plot in continuous corn. In this period clover failed three times and soybeans were used instead. They are not so effective as clover in improving soils.[2]

In 1914 an experiment[3] was started on two sets of plots of ten each. The average yields (43.2 bushels), of corn on the two sets of plots were the same the first year. On one set of plots a two-year rotation of corn and soybeans was used, leaving the cornstalks on the ground and returning the straw from the soybeans and using a winter cover crop of rye each year. On the other set of plots, corn was grown continuously, but the stalks were removed and no cover crop was used. Certain plots in both sets were similarly fertilized, with liberal applications. In the rotation, the average yield of corn from all plots for seven crops (alternate years 1915–27) was 54.7 bushels per acre, while for the same years, in the continuous culture, the average yield was 42.4 bushels. On the three unfertilized plots in the rotation, the average yield was 53.1 bushels, while on the three unfertilized plots in continuous culture it was 37.5 bushels

[2] See Kentucky Experiment Station Bulletin 331, Soils and Fertilizer Experiments, Experiment Station Farm, Lexington, 1932, for further details on the foregoing experiments.

[3] For details of this experiment see the article, "Renewed Experiments," in Bulletin 331, Kentucky Experiment Station.

for the same years. The average yield for the six plots in rotation not receiving nitrogen fertilizer was 53.3 bushels per acre, and for similar plots in continuous culture it was 38.7 bushels. The average yield in rotation for four plots receiving 160 pounds of nitrate of soda per acre alone or in combination with other fertilizer ingredients was 56.6 bushels per acre, and for similar plots for the same years in continuous culture it was 48.0 bushels per acre. The average yield of soybeans in the rotation was 14.3 bushels per acre.

While it cannot be determined to what extent the larger yields in rotation were due to rotation as such, how much to the residues returned, and how much to the cover crop, the experiment is a good illustration of the value of the combined practices in the rotation as against continuous culture with the land unprotected. The experiment also shows that soybeans can be so used as to maintain a fair nitrogen supply. The land on which these experiments were conducted was almost level, so that there was no serious erosion with continuous corn culture.

Soybeans are often planted with corn for hogging down. The Kentucky Experiment Station conducted tests, for from four to seven years, with soybeans planted with corn in the following ways, the tests being made in triplicate each year:

1. A hill of beans in each hill of corn (seven years).
2. Two hills of beans to each hill of corn, between hills (four years).
3. Drilled thick in corn rows (six years).
4. Alternate rows of corn and beans (five years).

The average yields of beans in the four methods were 3.7 bushels, 5.0 bushels, 10.8 bushels, and 10.2 bushels per acre, respectively. In each case the yield of corn was reduced about 2 bushels for each bushel of beans produced. If the beans and corn are hogged down and a grain cover crop is seeded early, the nitrogen fixed by the beans can be largely saved and the combination will be more valuable than corn alone, both for the hogs and for soil conservation.

There are many experiments on the soil experiment fields thruout the State that illustrate the extent to which soil

can be improved thru the use of legumes in rotation and the practical use of manure, once the land has been limed and fertilized. As an illustration, yield results are given from two sets of plots of the Campbellsville experiment field, which was begun in 1919. The rotation was corn, wheat and mixed grass and legumes. One set of plots was limed at the rate of 4 tons per acre in two applications of 2 tons of ground limestone each, between 1919 and 1923, and superphosphate (16 percent) was used on them at the average rate of 200 pounds per acre per year thru 1931, after which it was used at the rate of 100 pounds. No lime or fertilizer was used on the other set of plots. No manure was used until 1926, when it was applied at the rate of 5 tons per acre for corn on each set of plots. Six tons of manure per acre were applied to each set for corn in 1927, and 5 tons in 1928. Since then it has been applied to each set in amounts equal to the weight of the three crops harvested the previous year, wheat grain excepted. The yields obtained are given in Table 1.[4]

The hay mixture thru 1924 was red and alsike clover. Timothy was added in 1925, lespedeza in 1926, and alfalfa in 1927. Each was continued after its introduction. Second cuttings were obtained in 1929 and from 1933 to 1936 and are included in the above averages. In the later years some good yields of hay were obtained the year of seeding, but they are not included in the averages.

Three fields are required to accommodate a three-year rotation if each crop is to appear each year. Four and six-tenths tons of superphosphate and 12 tons of limestone have been used per three acres. From 1919 to 1936 this treatment has produced, on the three-acre basis, an increase of 434 bushels of corn, 118 bushels of wheat, and 15 tons of hay, exclusive of cuttings the year of seeding. Allowing 50 cents a bushel for corn, 75 cents for wheat, and $10.00 a ton for hay, the increase on three acres was worth $455 in round numbers, while the superphosphate at

[4] The first-year crops are not included. Corn failed in the drouth of 1930. There were two wheat failures and two hay crop failures. For details of the experiments see Kentucky Experiment Station Bulletin 322, Report on Soil Experiment Fields, 1931.

TABLE 1. Average yield per acre in a rotation of corn, wheat, and legumes and grass mixture.

	No Limestone or Superphosphate	Limestone and Superphosphate
Ave. first three corn crops	23.7 bus.	42.0 bus.
Ave. first three wheat crops	2.8 bus.	6.7 bus.
Ave. first three hay crops	860 lbs.	2303 lbs.
Ave. first three manured corn crops (1926-28)	35.6 bus.	62.5 bus.
Ave. three wheat crops (1927-29-30) (Wheat failed in 1928)	2.7 bus.	8.2 bus.
Ave. three hay crops (1928-30)	1170 lbs.	3910 lbs.
Ave. last three corn crops (1934-36)	37.3 bus.	63.9 bus.
Ave. last three wheat crops (1934-36)	2.6 bus.	13.2 bus.
Ave. last three hay crops (1934-36)	2237 lbs.	4957 lbs.
Ave. first eight corn crops	24.6 bus.	50.1 bus.
Ave. last eight corn crops	35.5 bus.	64.3 bus.
Ave. sixteen corn crops	30.0 bus.	57.2 bus.
Ave. first seven wheat crops	3.6 bus.	9.8 bus.
Ave. last seven wheat crops	5.9 bus.	16.5 bus.
Ave. fourteen wheat crops	4.8 bus.	13.2 bus.
Ave. first seven hay crops	1076 lbs.	3490 lbs.
Ave. last seven hay crops	2059 lbs.	3953 lbs.
Ave. fourteen hay crops	1568 lbs.	3720 lbs.

$18.00 per ton and limestone at $3.00 per ton cost $120, a gain of $335, or nearly $6.25 per acre per year. It should be remembered that this includes the lower yields at the beginning of the experiment. Also, by test, it has been shown that a reserve of phosphorus has been built up in the soil that will have a decided effect for several years without further applications. When crop prices are good, fertilizer may be used in heavier applications so long as the added increments produce increases that pay for the applications; thus a reserve may be built up in the soil that will make unnecessary the use of fertilizer in periods of low crop prices, except, perhaps, for crops of high value per acre, like tobacco.

Legumes in Pastures.[5] "Legumes are just as important in mixture with pasture grasses as they are in rotation with non-

[5] From Kentucky Extension Circular 272, Soil Management for Kentucky. 1934.

leguminous crops. An experiment on the Experiment Station farm at Lexington illustrates this point. In 1923, bluegrass was sown on land that would make 50 to 60 bushels of corn to the acre. With one part of it white clover was seeded, and all legumes were kept out of the other part. Volunteer sweet clover appeared on the legume plot and was allowed to mature, after which it was removed. The next year the bluegrass was harvested. The grass with the legume yielded 2400 pounds of hay per acre, and that without the legume 870 pounds. White clover was continued with the grass where the sweet clover had been. Usually the grass was clipped and left on the ground, but it was harvested twice more. The total yield of three cuttings of grass was 6100 pounds per acre on the legume plot, and on the plot without legumes it was 2600 pounds. Analysis of the grass at the grazing stage in two different years showed that the grass grown with the legume contained 33 percent and 44 percent more protein than the grass grown alone. At the end of eight years, 18 inches of soil under the grass without the legume had gained 62 pounds of nitrogen per acre, while 70 pounds were removed in harvested and dead grass. The soil under the legume and grass mixture had gained 406 pounds, while material removed contained 278 pounds, or a gain of nearly 700 pounds per acre. Grass had almost disappeared from the non-legume plot, altho there was a little gain in total nitrogen in the first 18 inches of soil, but on the grass-legume plot the grass was vigorous."

EXPERIMENTS IN PROGRESS

Rotation Experiments at Lexington. In 1920, rotation experiments were begun on the Experiment Station farm at Lexington (Maury silt loam) for the purpose of testing the effect of the preceding crop on wheat and for the purpose of determining the residual effect of different legumes in maintaining yields of corn and wheat. The rotations are:

1. Corn, wheat, clover.
2. Corn, wheat, orchard grass.
3. Tobacco, wheat, clover.

4. Corn, wheat, soybeans (in 28-inch rows to 1927; drilled solid since).
5. Corn, soybeans, wheat (beans in 28-inch rows to 1927; drilled solid since).
6. Corn, soybeans, wheat (beans drilled solid; cut for hay to 1927; afterwards threshed, straw returned on corn ground).
7. Corn, wheat, clover.

No fertilizer was used, as this soil is well supplied with the mineral nutrients. The plots were limed at the rate of 2 tons of ground limestone per acre, in 1927. No manure was used and no residues were returned, except as indicated in Rotation No. 6. The first year's growth of clover and of orchard grass was not harvested. A winter cover crop was always used in the soybean rotations when the ground was not occupied by a regular crop, including the wheat stubble.

The land on which this experiment is located was in soybeans in 1918, wheat in 1919, and clover in 1920. In 1920, after clover harvest, the first series of plots was plowed and planted to corn and tobacco, to get the effect of these crops in starting the rotation, but these crops are not included in this report. The second series of plots was put in corn and tobacco in 1921, following clover harvested in 1920. The yields of this year are of no value in comparing rotations. However, they have some value in showing the relative productivity of the plots occupied by the various rotations. After clover harvest in 1920, Series 300 was plowed. The appropriate plots were seeded to clover, orchard grass and wheat to complete the rotations. Red clover was used alone thru the seeding of 1930; since then, when the spring seeding failed, alfalfa was mixed with it for summer seeding. This was done four times. There were failures to get crops for harvest in 1926, 1928 and 1931. The yields of crops in these rotations are given in Table 2, on page 134

In Rotations 5 and 6 the average yields of corn thru 1928 were 46.5 bushels and 48.9 bushels, respectively—2.4 bushels in favor of No. 6. Beginning with 1928, the soybeans in Rotation 6 were threshed and the straw returned to the ground for corn the following year. The average yield of seven

TABLE 2. Yields of crops in rotation experiments.[1]

Period	Rot. 1 C-W-Cl	Rot. 2 C-W-OG	Rot. 3 Tob-W-Cl	Rot. 4 C-W-Sb	Rot. 5 C-Sb-W	Rot. 6 C-Sb-W	Rot 7 C-W-Cl
Corn, bushels; tobacco, lbs., per acre							
Average 1921-23	50.4	44.9	1477	53.1	45.9	45.6	47.5
Average 1934-36	50.8	46.4	1258	37.9	36.7	41.7	46.4
Average 15 crops[3]	59.2	54.3	1192	50.9	44.9	48.4	56.2
Wheat, bushels, per acre							
Average 1921-23	20.4	21.0	20.9	19.6	19.6	18.6	22.1
Average 1934-36	19.8	14.9	25.8	14.8	13.7	15.0	18.9
Average 15 crops	22.0	19.3	27.2	19.2	20.3	20.7	22.1
Hay, pounds, per acre							
Average 16 years	2935	1230	2633	4353	4015	——[2]	2668

[1] The corn crop of 1930 failed, and the crop of 1936 was very poor, on account of drouth. The wheat crop for 1928 was winterkilled. As there were three failures of clover and four failures of orchard grass to get large enough to cut, the hay of these crops is averaged on a basis of sixteen years for comparison with soybeans, of which there were no failures.

[2] The soybeans in Rotation 6 were cut for hay thru 1927, after which they were harvested for seed. The average yield of hay was 3943 pounds, as compared with 4000 pounds in Rotation 5. The average yield of beans in No. 6 for 1928-36 (exclusive of failure in 1930) was 13.9 bushels.

[3] For yields of crops by years thru 1931 see Ky. Exp. Sta. Bul. 331.

crops of corn affected by the returned straw was 47.8 bushels, while in Rotation No. 5 for the same period it was 43.0 bushels—4.8 bushels in favor of No. 6. The first wheat appeared in 1931 on land to which the bean straw was returned for corn. The average yields of wheat in Rotations 5 and 6 thru 1930 were 21.9 bushels and 21.5 bushels, respectively. From 1931 to 1936, the average yields were 17.7 bushels and 19.4 bushels, respectively—1.7 bushels in favor of No. 6. It appears that the return of soybean straw has affected the yields of corn and wheat favorably, but not very greatly.

In the fall of 1921 the plots of one of the three series used for the rotation were sampled for nitrogen determination, and again, in 1930, the same plots were sampled. The land slopes moderately from Rotation 7 to Rotation 1. The total gains or losses of nitrogen as pounds in 2,000,000 pounds of surface soil (7 inches) and 4,000,000 pounds of subsoil (11 inches), the approximate estimated weight of an acre of soil to those depths, were as follows:

Plot No.	Rotation	Loss or Gain
		Lbs.
201	Corn–wheat–clover	+ 707
202	Corn–wheat–orchard grass	— 10
203	Tobacco–wheat–clover	+ 88
204	Corn–wheat–soybeans	+ 1
205	Corn–soybeans–wheat	— 188
206	Corn–soybeans–wheat (beans drilled solid)	+ 200
207	Corn–wheat–clover	+ 347

It may occur to some one that, with the large increase in nitrogen in the soil of plots Rotations 201 and 207, assuming similar increases in the other plots of the corn-wheat-clover rotation, the yields of corn should have been higher and that the reason that they were not higher is because no fertilizers were used and a shortage of phosphorus or potassium may have developed. This experiment is on a high-phosphorus soil. That no serious shortage of potash has developed is shown by the yields in a similar rotation on adjacent land. On the unmanured check plots, the average yield for 1921–23 was 48.5 bushels against 48.9 bushels as an average of Rotations 1 and 7 for the same years. Where 10 tons of manure were used on each corn crop in duplicate tests from 1921 to 1936 the average yield was 61.8 bushels per acre against 57.7 bushels as an average for Rotations 1 and 7 for the same period. The evidence is that lack of moisture is the reason for yields not being higher. Seldom is there sufficient moisture properly distributed for maximum corn yields here. Four tons of manure on each corn crop in the above tests produced 59.4 bushels against 61.8 bushels for 10 tons, as stated above. However, such cropping practices as

are used in these rotations will ultimately develop a potassium shortage, as has been shown by other experiments.

It is evident from these results that clover is much superior to soybeans in the maintenance of nitrogen. It appears that soybeans drilled solid are more effective in nitrogen conservation than drilled in rows and cultivated. The corn yields up to the time soybean straw was returned in Rotation No. 6 were greater for Rotation No. 6, altho they were equal for the first round of the rotation.

Adjacent to these rotations is a rotation of corn, wheat and clover, in which manuring experiments are being conducted. In the experiment there are six check plots in each of the three series, to which no manure is applied. Clover failed and soybeans for hay were substituted four times (1921, 1924, 1926, 1928), while in the rotation experiments under discussion clover was always reseeded when the regular seeding failed. Altho in 1926 and 1928 the reseeding did not make sufficient growth for harvest, there was some clover which benefited the corn the following year. For the years 1922, 1925, 1927 and 1929, where corn followed soybeans substituted for clover the average yield of corn on unmanured check plots in the manuring experiment was 38.4 bushels per acre, while in the rotation experiments where soybeans were not substituted for clover the average yield of corn following the clover in duplicate rotations was 50.6 bushels per acre, an increase of 12.2 bushels, or about 32 percent greater following clover. The yields of corn on the same plots in 1924, 1926, 1928 and 1931, when corn followed clover on all of them, were 62.3 bushels on the unmanured checks in the manuring experiments and 69.4 bushels in the rotation experiments, a difference of 7.1 bushels, or about 11 percent. Observations of the growing corn accorded with the results.

The average yield of the six check plots in the manure rotation for 1921–23 was 47.8 bushels with the crop of 1922 following soybeans substituted for clover when it failed. The average yield for Rotations 1 and 7 for the same years

was 48.9 bushels—showing that little difference existed in the productivity of the soil at that time. If the 1921 and 1923 crops are compared, there is a difference of 0.7 bushels in favor of the manure rotation check plots.

These results show clearly the superior residual effect of clover to soybeans. As previously stated, the object was to get the residual effect of these rotations unobscured by any effect of manure or residues returned except as noted.

It is worthy of note that the yield of soybean hay in Rotation No. 4 was 12 tons greater in sixteen years than the yield of clover hay in Rotations No. 1 and No. 7. Had manure made from feeding the crops in both rotations been carefully saved and returned, it is probable that the yields of corn and wheat would have been as good in the soybean rotation as in the clover rotation. However, manure is seldom saved fully enough to offset the difference between the effects of the two rotations. Beginning with 1937, manure will be applied to all plots for corn and tobacco.

Legumes in Rotation at the Western Kentucky Substation. In a rotation experiment at the Western Kentucky Substation, on soil of limestone origin,[6] various legumes and timothy are used as the third-year crop in rotation with corn and wheat. The purpose of the experiment is to determine the residual effect of the legumes and grass on the yield of corn and wheat. The plan of the experiment provides that from time to time the nitrogen content of the soil shall be determined and compared with the content at the beginning of the experiment. The experiment was begun in the fall of 1926, but the corn and wheat crops of 1927 are not used in the average yields because they were not affected by preceding legumes. Limestone, where used, was applied at the rate of 2 tons per acre when the experiment was begun. Reliming was begun on the series of plots in corn in 1936 and the other two series will be relimed in 1937 and 1938. Superphosphate was used at the rate of 300 pounds (16 percent) on corn, and 300 pounds on wheat. Muriate of potash

[6] The soil has not been classified by the United States Bureau of Soils, but it is believed to be Decatur silt loam.

was applied at the rate of 100 pounds per acre on Plot 15 when wheat was sown, to determine its effect on alfalfa. Sulfate of ammonia was used on Plot 24 at the rate of 100 pounds per acre for each crop, except that it was not used on timothy prior to 1930. On Plot 20, beginning in 1929, manure has been applied for corn at the rate of 3 tons for each ton of clover hay harvested the preceding year. Table 3 gives the average yields of crops thru 1936. As corn was practically a failure in 1930 because of drouth, the yields for that year are not included in the average, for to do so would obscure to some extent the normal effects of the legumes on yields. The corn yields of 1936 were much below average, but are included. Wheat was a failure in 1928.

For some cause not determined, good stands of alfalfa and sweet clover were not obtained, and the yields were low. The yields of sweet clover seed were very low. On Plot 20, where manure was used, the average yield of clover hay was lower than on Plot 17, where manure was not used. This difference is due very largely to the difference in yield for one year when clover was a good stand on Plot 17 and yielded 4540 pounds, whereas the first seeding failed, for some unknown reason, on Plot 20, was reseeded in the spring of the year of harvest, and yielded 2100 pounds.

Outstanding results of these tests are:

1. The large effect of limestone and phosphorus on the yield of lespedeza.
2. The low yields following cowpeas and soybeans, including the plot to which soybean straw was returned.
3. The effectiveness of lespedeza, particularly on soil treated with limestone and superphosphate.
4. The effect of clover or clover and timothy as compared with timothy alone or with timothy alone and sulfate of ammonia as a source of nitrogen on all the crops in the rotation.
5. The ineffectiveness of clover plowed under as compared with clover harvested.

It will be observed that the yields of cowpea and soybean hay were larger where only phosphate was used than the yields

TABLE 3. Average yields per acre of crops in rotation with various legumes and grass (corn and wheat in bushels; hay in pounds). See footnote[1] for explanations.

Plot No.	Treatment	Third-Year Crop and Its Use	Corn, 8 Crops		Wheat, 8 Crops		Hay, 9 Crops	
			Yield	Increase	Yield	Increase	Yield	Increase
1	O		28.7	———	4.6	———	866	———
2	P	Lesp. plowed under	43.1	13.9	11.9	6.9	———	———
3	P	Lesp. for hay	36.9	7.2	11.0	5.5	2067	1076
4	O		30.1	———	5.9	———	1053	———
5	LP	Lesp. for hay	49.2	17.3	14.6	8.2	3489	2394
6	P	Cowpeas for hay	33.4	—0.3	8.7	2.5	3082	1946
7	O		35.5	———	6.4	———	1178	———
8	P	Soybeans for hay	35.2	—0.8	8.8	2.0	3313	2000
9	P	Soybeans for seed	39.8	3.2	10.0	2.8	4.9[2]	———
10	O		37.1	———	7.6	———	1584	———
11	LP	Sw. cl. hay 1st yr.; seed 2d yr.; straw returned	55.2	18.5	14.9	7.9	1975	413
12	LP	Alf. for hay; last crop turned under	48.7	12.5	13.6	7.2	1569	30
13	O		35.8	———	5.8	———	1517	———
13a	O		35.4	———	6.7	———	1364	———
14	LP	Alf. for hay	48.3	13.9	13.7	7.1	2162	833
15	LPK	Alf. for hay	46.5	13.0	13.2	6.6	1996	703
16	O		32.5	———	6.5	———	1258	———
17	LP	Clover for hay	53.0	18.8	16.7	9.6	2742	1346
18	LP	Clover plowed under	55.5	19.6	17.4	9.6	———	———
19	O		37.6	———	8.4	———	1671	———
20	LPM	Clover for hay	54.4	19.0	17.5	9.8	2398	882
21	LP	Timothy for hay	39.1	6.0	10.1	3.1	1880	518
22	O		30.9	———	6.3	———	1207	———
23	LP	Cl. and tim. for hay	47.8	15.1	13.6	6.6	2761	1423
24	LPN	Timothy for hay	46.7	12.1	14.5	6.7	2752	1283
25	O		36.4	———	8.5	———	1600	———

[1] O = no treatment; L = limestone; P = superphosphate; K = muriate of potash; M = manure; N = 100 pounds sulfate of ammonia used on each corn and wheat crop and on timothy since 1930.

The increases are calculated from the check plots by assuming a uniform variation between check plots.

The third-year crop on the check plots was a mixture of red and alsike clovers, common and Korean lespedeza, except the 1936 crop, which was red clover, Korean and Kobe lespedeza. However, the hay crop was practically all lespedeza.

The lespedeza on Plots 2, 3 and 5 was a mixture of common and Korean for the first four crops, Korean alone for the next four crops, and a mixture of Korean and Kobe for the 1936 crop.

[2] Seed, bushels. Straw returned.

of clover and alfalfa hay where limestone and phosphate were used. If manure were returned from feeding corn, corn stover and hay, and using straw for bedding, it is possible that the yields of corn and wheat would be as good following cowpeas or soybeans as following clover and lespedeza. Manure is not

generally well saved. Furthermore, cowpeas and soybeans are expensive to grow, because of the extra plowing of the land and the cover crop that is and should be used between them and corn in these tests, and should be used in general practice.

It is quite likely also that considerable leaching of nitrogen from the soil takes place between wheat harvest and the following cowpea or soybean crop, because no winter cover crop is used on the stubble land.

In lespedeza rotations, there is no doubt considerable leaching of nitrogen from the soil in both the first and second winters following its seeding, because no winter cover crop is used. Lysimeter experiments (see Page 143) show much leaching from soil occupied by lespedeza when no grass or cover crop is used with the lespedeza. Where grass is not sown with lespedeza, a winter cover crop of grain should be seeded on the disked lespedeza stubble as early as practicable.

If lespedeza is not grazed too closely—and it is not often that this happens—enough seed matures for self-seeding where the sod is disked for a winter cover crop. If lespedeza is cut for hay early enough and high enough to leave some seed-bearing branches, it reseeds itself when disked for a winter cover crop. If it is cut after seed has matured and it is desired that it reseed itself, care will have to be taken to cut it high enough to leave some seed. Where the stand is very thick, as is generally the case with a self-seeded crop, there may not be any seed low enough on the plants for self-seeding when cut for hay.

Perhaps the largest amount of nitrogen fixed was on Plot 5, but conditions were favorable for leaching there because of the dead legume material left on the ground in the first year's growth of lespedeza, which was not harvested, and in the second-year stubble. Conditions were favorable for leaching on Plot 11 also, with the sweet clover dead and the straw lying on the ground. Had winter cover crops been sown on all the plots preceding corn, the gains and losses of nitrogen doubtless would have been different. The purpose was to test usual practices.

A study was made of the nitrogen content of the first 18

inches of the soil of each plot in one of the three series used in this rotation. Soil samples were taken from each plot at the beginning of the experiment, and samples were taken again from near the same places on each plot in September, 1936, following corn. Samples for similar studies will be taken following the corn crops in 1937 and 1938. Total gains or losses of nitrogen as pounds in 2,000,000 pounds of surface soil (7 inches) and 4,000,000 pounds of subsoil (11 inches), the approximate estimated weight of an acre of soil to those depths, were as follows for the plots sampled in 1936:

	Gain (+) or Loss (—) Lbs.
Average of all check plots	— 179
Plot 2—Lespedeza plowed under	+ 41
Plot 3—Lespedeza for hay	— 207
Plot 5—Lespedeza for hay	— 31
Average of Plots 6 and 8—cowpeas and soybeans for hay	— 220
Plot 9—Soybeans for seed, straw returned	+ 52
Plot 11—Sweet clover (see Table 2)	+ 86
Average of Plots 12, 14, 15—alfalfa for hay	+ 49
Plot 17—Clover for hay	+ 149
Plot 18—Clover plowed under	+ 72
Plot 20—Clover for hay, manure on corn	— 60
Plot 21—Timothy for hay	— 60
Plot 23—Clover and timothy for hay	+ 153
Plot 24—Timothy for hay, 100 lbs. sulfate of ammonia on each corn and wheat crop and on timothy since 1930	+ 131

The net gain or loss of nitrogen does not, of course, tell how much was lost by leaching. However, when considerable dead material is left on the ground, as was the case with all the legumes in these tests except alfalfa, there will be loss of nitrogen by leaching.

Where lespedeza is to be used for pasture or hay, without doubt its best use is in mixture with grass. In general, under Kentucky conditions, a three-year rotation is too short if enough land is available to extend it. The rotation should be lengthened as much as practicable by growing grass with the

legume and using the mixture for pasture and hay as long as conditions permit. By producing plenty of pasture and hay by good soil treatment, livestock can be maintained a much longer period on pasture and with less grain and concentrates the remainder of the year. Good cover crops may also be used for pasture and further reduce the grain required for feed. Pasture and hay produced on properly limed and fertilized soil are also more nutritious than when produced on soil deficient in plant-food elements. The value of good pasture and hay is strikingly illustrated in the Bluegrass region, where in some counties three-fourths or more of the land is kept in grass for pasture and hay. Also, this method of cropping is the best preparation of soil for both Burley and dark tobacco. While complete fertilizers are profitable on tobacco under most conditions, they cannot take the place of good soil management in preparing the land for the crop.

Lysimeter Experiments. Lysimeter experiments were begun at Lexington in October, 1933, with Maury silt loam. The soil container part of the lysimeters is 22 inches in diameter and 24 inches deep, with a basin under the soil, separated from it by a perforated iron plate. The drainage water is removed from the basin by pumping thru an iron pipe leading from the basin to the top of the lysimeter. All lysimeters except one pair were seeded to rye in October, 1933, with the following crops on duplicate lysimeters thereafter.

None	
Bluegrass	Korean lespedeza and winter cover crop of rye.
Korean lespedeza	Korean lespedeza and bluegrass.
White clover	White clover and bluegrass.
Red clover	Red clover and bluegrass.
Alfalfa	Alfalfa and bluegrass.

The object of the experiment is to determine losses from leaching under the different crops and to determine nitrogen fixation and accumulation in the soil, the hypothesis underlying the experiment being that, in addition to preventing leaching of nitrogen, grass in association with the legume may, by competi-

tion for soil nitrogen, cause greater fixation by the associated legume. The experiment has not been under way long enough to provide sufficient data to draw conclusions for all the tests involved, but certain results are significant enough to warrant their publication at this time.

Because of failure of bluegrass to make a stand with lespedeza, there were six lysimeters that had practically only lespedeza on them in the fall of 1934. These were handled in duplicate in different ways, with the results indicated below.

	Nitrogen leached Oct. 1, 1934, to June 30, 1935
Korean lespedeza undisturbed	56 lbs. per acre
Korean lespedeza disked into soil Oct. 1 and seeded to rye	2 lbs. per acre
Korean lespedeza disked into soil Oct. 1, no cover crop seeded	127 lbs. per acre

In the fall of 1935 the Korean lespedeza on two lysimeters was clipped and removed, leaving a stubble about 2 inches high, without a winter cover crop. The average nitrogen leaching from these two lysimeters was:

October 1, 1935, to March 31, 1936,	48 lbs. per acre
April 1, 1936, to June 30, 1936,	14 lbs. per acre
Total	62 lbs. per acre

The middle of September, 1934, a crop of Korean lespedeza yielding perhaps 2 tons of hay per acre was disked into the soil in small duplicate plots on the Experiment Station farm. No cover crop was seeded. The average amounts of soluble (nitrate) nitrogen at different dates thereafter were as follows:

Depth, inches	Nov. 30	Jan. 7	Mar. 4	April 10
0–6	16.4	25.4	9.7	4.7
6–18	11.4	21.8	19.3	6.1
18–30	—	—	20.0	8.3
30–42	—	—	—	6.1
42–54 (rock)	—	—	—	3.3
Totals	27.8	47.2	49.0	28.5

Precipitation during the period, in inches, was: October, 0.68; November, 3.41; December, 2.51; January, 5.11; February, 1.87; and March, 7.52. Precipitation was less than normal except during January and March, and hence leaching probably was less than during an average year.

In the same study there were other plots where the Korean lespedeza was disked in and rye seeded. Very little soluble nitrogen was found in the soil at any time, and none after November 30.

The following results from certain other lysimeters are significant:

	Loss of Nitrogen Oct 10, 1933, to Mar. 31, 1936
No vegetation	310 lbs. per acre
Bluegrass	17 lbs. per acre
Alfalfa	15 lbs. per acre
Alfalfa and bluegrass	7 lbs. per acre
Korean lespedeza and bluegrass	86 lbs. per acre

The Korean lespedeza kept the bluegrass from making much growth, so that the cover was mostly lespedeza. However, it is quite certain that where lespedeza is in mixture with a good stand of grass, practically all leaching of nitrogen will be prevented.

The drainage from the lysimeters was, of course, greater than from 2 feet of soil in natural position, for the reason that in the lysimeters there is no resistance to drainage from underlying soil, and also for the reason that there is little or no surface run-off from lysimeters, while from a soil in natural position, which nearly always has some slope, there is a great deal of surface run-off. The surface of the soil in the lysimeters is level and a little below the top of the cylinder walls. However, while losses from soils in natural position are not so great as in lysimeters, doubtless the losses vary under different crop cover conditions just as they do in lysimeters. It is well to remember that in the limestone regions of Kentucky water passes thru the soil and

is carried away rapidly thru the underground passages characteristic of a limestone area.

Effect of Legumes on Bluegrass. Studies are being made on the effect of various legumes on the yield of bluegrass on the Experiment Station farm at Lexington. Following is a brief summary of some of the more important results obtained. The yields are of cured material on the basis of 10 percent of moisture in the hay.

1.	Bluegrass alone (average 1930-34)	1945 lbs. per acre
2.	Bluegrass from plots on which legumes were associated with bluegrass but had disappeared before the harvest of bluegrass crops used in this average (average 1930–34)	2950 lbs. per acre
3.	Bluegrass alone (average 1929–35)	1977 lbs. per acre
4.	Bluegrass with which red clover, white clover, sweet clover, lespedeza and alfalfa were seeded in the beginning, but from which the legumes wholly or partially disappeared. Legumes except red clover, and sweet clover included in harvest with grass until disappearance (average 1929–35)	3580 lbs. per acre

THE UTILIZATION AND CONSERVATION OF NITROGEN

It is the opinion of the writer that, under Kentucky conditions, the fixation, utilization and conservation of nitrogen is the largest problem in soil improvement and conservation for the following reasons:

1. Crops generally require more nitrogen than any other nutrient element that may have to be applied to the soil and, if purchased, would usually cost more per unit of crop produced.

2. Nitrogen is more subject to loss by leaching than are other nutrient elements that have to be applied to Kentucky soils, for the reason that whenever the weather is warm enough for plant growth, soil organic matter decomposes and soluble nitrogen is developed in the soil and is subject to leaching unless there is some growing crop on the land that will use it all.

3. In the process of becoming soluble, nitrogen is converted into nitric acid, a very strong acid which combines with important elements in the soil, such as calcium (lime) and potassium, among other elements, to form soluble compounds which are subject to leaching, thus causing a loss of these mineral nutrients as well as of nitrogen.

The only means of preventing these losses is to have the land covered as much of the time as possible with a growing crop. The ideal cover is a mixture of grass and legumes. Any perennial grass may be used, such as timothy, redtop and orchard grass. Where the land can lie in grass for several years, the ideal grass is bluegrass, provided the land is put in condition for growing it.

Practically any soil in the State, if it is limed and liberally fertilized with phosphate, will produce good bluegrass when legumes are grown with it, as has often been demonstrated. In regular rotations containing intertilled crops like corn and tobacco the intertilled crops should be followed by grass and legumes for as long a period as practical (see Kentucky Extension Circular 272 for suggestions on rotations).

All intertilled crops should be followed by winter cover crops, which should be seeded as early as possible, so that they may make a large growth and take up as much nitrogen as possible. If the land is rich and barley can be seeded by September 15, it has no superior as a cover crop, except that it sometimes winterkills. Both rye and wheat are good cover crops. The importance of cover crops and of early seeding is well illustrated by the following experiments formerly reported.[7]

On fertile soil on the Kentucky Experiment Station farm at Lexington, on which tobacco was grown, barley was sown after the tobacco was removed, while a small area was left bare. On November 30 the barley had taken up 156 pounds of nitrogen per acre, with 19 pounds per acre of soluble nitrogen left in the first 8 inches of soil. In the bare soil there were 69 pounds of soluble nitrogen per acre in the first 8 inches, a difference of

[7] Kentucky Extension Circular 272. Soil Management for Kentucky.

106 pounds of nitrogen that presumably had already passed below the first 8 inches of soil by November 30. Other tests on the farm showed that most of the soluble nitrogen in the soil in the fall passes below the first 2 feet of soil by the last of March. The nitrogen lost from the soil without a cover crop was 156 pounds greater than with the cover crop, an amount equivalent to about 1000 pounds of nitrate of soda or 800 pounds of sulfate of ammonia.

A similar test was made on a less fertile soil on the Kentucky Experiment Station farm, in which certain cover crops were sown at different dates following the harvesting of tobacco. The results were as follows:

	Nitrogen per acre in plants and soluble nitrogen in 2 feet of soil in December	
Crop and Date of Sowing	In plants	In soil
Barley seeded September 11	46 lbs.	3 lbs.
Barley seeded October 10	20 lbs.	19 lbs.
Wheat seeded October 10	10 lbs.	32 lbs.
Wheat seeded November 7	2 lbs.	35 lbs.

By the end of the following March, practically all the soluble nitrogen had disappeared from the first two feet of soil. In this test the nitrogen lost from ground seeded to wheat on October 10 was the equivalent of 200 pounds of nitrate of soda, while there was practically no loss from the land seeded to barley on September 11.

Many soils in the State have become so exhausted of organic matter (humus) that there is not much nitrogen left in them to become soluble and leach, and they therefore do not produce a cover crop vigorous enough to prevent erosion, which is also a cause of great loss of soil and therefore of all plant nutrients. One highly important reason for keeping up a good supply of nitrogen by growing legumes is that a crop cover can be grown vigorous enough to prevent erosion. If ground is so worn that it will not support a good cover, then the imperative thing to do is to begin to improve it by growing legumes. In most cases of

this kind, success will be dependent upon liming and phosphating the land for the legume.[8]

Important in conserving and utilizing nitrogen fixed by legumes is the proper saving and utilizing of manure made by feeding legumes and other crops. A large part of the nitrogen and potassium in the feed given to animals is voided in the urine. Unless sufficient bedding is used, large losses occur; and unless the manure is protected against heating and leaching, there will be large losses of nitrogen even if all the urine is absorbed by bedding.[9]

It is best to apply manure to non-legume crops in the rotation, principally on corn and tobacco in general farming. If manure is applied for a legume, it may furnish a considerable part of the nitrogen required by the legume and reduce the amount taken from the air. Manure applied to corn is not completely used by the corn. If soybeans or cowpeas or other legumes follow the corn, they may take a considerable part of their nitrogen from the residue of manure, and therefore fix less from the air. It seems to the writer that cowpeas and soybeans should be used primarily as emergency crops when other legumes fail, and that it is better to follow corn and tobacco with small grain in which grass and legumes will be sown to remain for two years or longer. For example, it is better to use a rotation of corn, wheat, and two years of legumes and grass than to use a rotation of corn, soybeans, wheat and clover.

Manure dropped on pasture land is generally poorly utilized because the dunghills are not scattered. When not scattered, the concentration on small plots is much greater than is needed, and animals do not eat readily the more vigorous grass around the dunghills, as is readily observed on many bluegrass pastures. The dunghills may be broken up and scattered by various dragging devices that the farmer may make. A section harrow may be adjusted for the work. One device consists of a

[8] Kentucky Experiment Station Bulletin No. 322 gives the results of practical experiments in improving worn soil.

[9] See Kentucky Extension Circular No. 153 on the production and care of farm manure.

number of old automobile tire rims loosely bolted together to form a flexible drag.

Manure spread in warm weather, as in the spring for corn and tobacco, should at once be well disked into the soil, as it may contain nitrogen in the form of ammonia, a large part of which may be lost by volatilization on a warm day. When put out in the field in small piles, losses will take place by volatilization, and if rained upon, loss of effectiveness will take place by leaching into the small area under the pile.

Stalks, straw and other crop residues are best utilized for bedding. They absorb urine, which makes them decompose more effectively than if applied directly to the soil. Stalks and straw plowed under on unmanured land may lower the yield of the first crop following.

SUMMARY AND SUGGESTIONS

The solution of the problem of the fixation, utilization and conservation of a sufficient supply of nitrogen involves many factors of vital importance.

1. An ample supply of nitrogen is necessary to the maintenance of a vigorous ground cover to prevent soil erosion and all its attendant evils.

2. With an abundance of nutritious pasture and hay, livestock will require less grain feed, and not so much land has to be plowed for corn, thus protecting more land against erosion and leaching. The effect of pasture and hay in reducing tilled crops is well illustrated in the better parts of the Central Bluegrass region, where two-thirds to three-fourths of the land is kept in grass and a large livestock population is maintained. The type of agriculture in which grass predominates is also best for both Burley and dark tobacco, Kentucky's chief cash crops.

3. The production of legumes to supply nitrogen for high yields of non-leguminous crops, including grasses, implies the application of sufficient mineral nutrients in which the soil may be deficient to make a vigorous growth of legumes possible. They are principally lime and phosphorus.

4. The conditions necessary for the production of vigorous legumes are also necessary for the production of crops of high nutritive value. Crops, including legumes, produced on soil deficient in mineral plant nutrients contain, as a rule, lower percentages of nitrogen (and therefore less protein) and mineral nutrients necessary to the proper nourishment of farm animals and human beings than do crops produced on fertile soil. The primary object of the production of human food and animal feed crops is human nutrition. Neither animals nor human beings can be properly nourished upon crops grown upon impoverished soil. It is an obligation to the present and future generations to conserve the soil in a fertile condition for the production of highly nutritious food and feed plants.

Use of Steep Land. Where a large part of the farm is steep and subject to erosion, it is advisable to keep as much as possible of the steep land in pasture and hay crops, giving it the necessary treatment to make it favorable for vigorous growth of the crops. The grasses used should always have legumes with them. Under these conditions it is advisable to produce the necessary grain for feed on the more level land, in short rotations, making the land as productive as is economically feasible. A two-year rotation of corn and small grain may be used. Barley may be used if the land is fertile and the corn is harvested early enough, as may be done when it is used for silage or when an early variety is used for grain, thus getting two grain feed crops each year.

A two-year rotation of corn and wheat on the Hopkinsville soil experiment field[10] illustrates the possibilities of such a rotation. Rather thin land was limed and treated with superphosphate. Sweet clover was sown on the wheat in the spring and turned under the next year for corn. The yield of corn for the first three years (1922–24) was 25.5 bushels per acre, and for the last three years (1927–29) was 54.7 bushels. Manure was used on the corn in 1926-27 at the rate of 6 tons per acre. The average yield of corn for the eight years was 43.2 bushels. Reg-

[10] See Kentucky Experiment Station Bulletin No. 299, a report on the Hopkinsville soil experiment field, which was operated from 1922 to 1929.

ular use of manure would no doubt have greatly increased the yields, but it was not regularly obtainable.

In a three-year rotation of corn, wheat and red clover on adjacent land not limed or phosphated, the yield of corn for the first three years was 18.9 bushels per acre, and for the last three, 31.1 bushels. In the three-year rotation on land treated with limestone and superphosphate, the yield was 24.8 bushels for the first three years and 49.4 bushels for the last three. Manure was used at 5 and 6 tons per acre on the corn in 1927-28, on both the fertilized and unfertilized plots.

While the effects of the two rotations on the yield of corn are not strictly comparable, because the productivity of the soil differed somewhat in the different cases cited, the very large increase in the yield of corn is highly significant and indicates the possibilities of a short rotation. Lespedeza may be used instead of sweet clover, but it should be followed by a cover crop, which may be seeded by disking the sod. It may also be mixed with sweet clover. Sweet clover should be plowed under by the last of April when it is to be followed by corn. The land in a short rotation like this should be liberally manured if possible. If barley is used, it may be advisable to top-dress with nitrogen, for it requires a liberal supply of nitrogen.

It is not best to try to produce corn in continuous culture, even tho the land may be liberally manured. An experiment on the Experiment Station farm at Lexington[11] indicates that it is not possible to maintain a high yield of corn in continuous culture, tho the land is fertile to begin with and is liberally manured thereafter. The experiment was begun in 1920, on land that yielded 70 bushels per acre the first year, without manure or fertilizer. Fifteen tons of manure per acre had practically no effect on yield the first year. The average yield of the unmanured check plots for eleven crops was 32.6 bushels per acre, while on the plot manured at the rate of 15 tons per acre in alternate years the yield was 45.5 bushels per acre. Ten tons of manure was as effective as 15 tons. A rye

[11] See Kentucky Experiment Station Bulletin 331.

cover crop was used each winter. In a three-year rotation of corn, wheat and clover begun at the same time on adjoining land not quite so fertile, the average yield for the same period was 51 bushels per acre without the use of manure and 60 bushels per acre with the use of 4 tons of manure per acre for each corn crop.

Care in Use of Lime. While it is important to use lime to produce a satisfactory growth of legumes, it is very important not to lime land heavily on which tobacco is to be grown, and not to apply lime immediately preceding tobacco, for such practices may injure tobacco, altho injury does not always follow these practices. The lime should be applied as far ahead of tobacco as can be done in preparing the land for tobacco, and should be used at as low a rate as will produce the legume. One ton of ground limestone per acre is usually sufficient for this purpose, but there is little danger from 2 tons if four or five years intervene between its application and the tobacco crop.

Advantages of Alfalfa. Alfalfa has advantages for a hay crop that have not been fully recognized by Kentucky farmers. It can be grown on any soil with good underdrainage, provided it is supplied with sufficient lime and mineral nutrients. One of its chief advantages is its adaptation to Kentucky rainfall conditions that often produce critical periods that prevent getting a stand of other legumes, like red clover, or may make lespedeza hay crops very short. Alfalfa may make a good first cutting, survive a severe summer drouth, and produce another good cutting in the fall, as was the case in 1936, when second-year alfalfa in a four-year rotation of corn, wheat and two years of alfalfa produced 5185 pounds of hay per acre in three cuttings. The first-year alfalfa produced 2825 pounds per acre in two cuttings. The stand was not injured by the severe drouth. Another very great advantage of alfalfa is its long life, and therefore the small cost of seeding when the number of cuttings is considered.

Where alfalfa is regularly grown on a farm, it should be rotated and not kept more than about four years on the same land. It is good practice to sow a grass with alfalfa, particu-

larly on sloping land. It is an excellent way to get a good stand of bluegrass, which prevents erosion and makes good pasture when the alfalfa is no longer used for hay. When alfalfa is plowed up, the land should be liberally manured or fertilized with mineral fertilizers before going back to alfalfa, for it makes a very heavy draft on mineral nutrients, particularly potash.

Adapted Red Clover. Red clover is an excellent legume for general cropping systems where the soil is put in condition for growing it by proper liming and fertilizing. However, many failures of clover occur on land properly prepared for it because unadapted seed is used. The Kentucky Experiment Station is making extensive tests of the adaptation of clover from various sources. The tests on the Western Kentucky Substation are illustrative of the importance of using seed of adapted strains. The results given below are the averages of the first cuttings for four years:

	Lbs. of Hay Per Acre
Adapted Kentucky-grown seed	4375
Unadapted Kentucky-grown seed	2510
Tennessee anthracnose-resistant seed	3800
Seed from northern states	2735
Seed from northwestern states	2195
Seed from European countries	2040

In 1932, when only Kentucky-grown seed was used in the tests, the adapted strains yielded 5260 pounds per acre for the first cutting and 2930 pounds for the second cutting, a total of a little more than 4 tons per acre. In the drouth year of 1936, clover from Kentucky-grown adapted seed yielded 2518 pounds of hay per acre for the first cutting on the Experiment Station farm at Lexington, while the first cuttings from foreign and northwestern United States seed averaged 965 pounds per acre. At the Western Kentucky Substation, the yield of hay from Kentucky-grown adapted seed was 5500 pounds per acre, and from northwestern United States seed it was 3450 pounds.

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FAMILY INCOMES AND LAND UTILIZATION IN KNOX COUNTY

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Bulletin No. 375

Family Incomes and Land Utilization in Knox County

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Knox County, situated in southeastern Kentucky and separated by only one county from the states of Virginia and Tennessee, is typical of the 38 counties or parts of counties which comprise the mountain region of eastern Kentucky. This region, which is part of the Cumberland Plateau, borders Ohio and West Virginia on the East, Virginia on the Southeast and Tennessee on the South. Its approximate western border may be indicated by a line extending southwestward from the northwestern corner of Greenup County on the Ohio River to the Southwestern corner of Wayne County on the Tennessee border.

The topography of this area is largely steep hillsides and narrow valleys. The surface rocks are sandstones and shales. The hillside soils are mostly silt loams and sandy loams usually containing sandstone and shale fragments. They are of low productivity for most of the field crops grown in the region, but produce good timber. The slopes facing east and north generally have deeper soil and are therefore better fitted for tillage than those facing west and south. The alluvial, or bottom, soils are sandy, silt or mixed loams. Practically all the soils in the area are strongly to moderately acid, deficient in phosphate and in humus. On the whole, the bottom soils, if well drained, are considerably more productive than the hillside soils. This is particularly true if flood waters occasionally leave a good silt cover.

This region comprises about a fourth of the area and population of the state. Forty-seven percent of the families are classed as farm families by the federal census, but there are as many rural

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non-farm families, the area being populated largely by workers in coal mining and other non-farming occupations, a large proportion of whom live in the open country. The area as a whole is poorly adapted to agriculture. Because of the deeply dissected land surface, narrow valleys, steep slopes, and sharp ridges, there is very little good farming land.

The lack of an adequate acreage of suitable land in this region in relation to the number of persons living on the land, coupled with the lack of opportunities for non-farming employment, has resulted in much poverty. Over a considerable period the people in this region derived a large proportion of their incomes from lumbering and coal mining. Of a group of 228 typical farm families in Knott County, in 1930, only 22 derived their living mainly from farming, and most of the land which they cultivated was steep and eroded hillside. Since 1929 the opportunities for acquiring an income from non-farming sources have decreased to a considerable extent. Furthermore, many families who had previously left their home communities to engage in mining and other industrial occupations were forced, by the shutting down of these industries, to return to the communities from which they had migrated. A careful estimate made by county agricultural agents of these counties at the instance of the President's Organization on Unemployment Relief indicated that 7600 families returned to 22 of these counties during the two years prior to March 1, 1932, and thereby increased by one-sixth the families in the area. During a considerable part of the two-year period following 1932 more than half of the families in the area were on public relief.

The population per square mile in this area is greater than that of many of the more level and fertile agricultural counties of Kentucky. For example, the 1930 Census shows the population per square mile for Knott, Magoffin, and Laurel Counties in this area to be 44, 52, and 47, respectively, as contrasted with population of 41, 41, and 59, respectively, in the three rich agricultural counties, Henry, Shelby, and Bourbon, in the Bluegrass region of Central Kentucky. Two-thirds of the counties in the Kentucky mountains gained 20 percent in population during the decade from 1920 to 1930.

The marked disparity between this and the better agricultural sections of Kentucky in the resources which condition standards of

living is exemplified by contrasting Laurel County in this area with Bourbon County in central Kentucky. The amount of land in farms in the two counties is practically the same. Much of the tillable land in Laurel County is submarginal for farming. Practically all the land in Bourbon County is highly productive. The farm population in Laurel County is nearly twice that of Bourbon County. Laurel County has less than one-third as many acres of tillable land per person as Bourbon County. There are nearly twice as many children of school age in Laurel County as in Bourbon County, but the property subject to assessment for school or other purposes in Laurel County is only one-tenth of that of Bourbon County. Thus the local tax base for support of schools in Laurel County is only one-tenth that of Bourbon County.

SCOPE AND OBJECTIVES OF THE STUDY

This is one of a series of economic and social studies begun in 1929 which were undertaken to throw light on the problems of land utilization and conditions of living in the Eastern Kentucky Mountain region which have become increasingly acute during recent years. The principal objectives were: to classify and show the present use and condition of land, particularly as to its slope, degree of erosion, productivity, and present and prospective ability to afford a living for its occupants; to ascertain whether and to what extent reforestation should be encouraged; to obtain data on family incomes, costs of and returns from crops associated with the various land classes and ranges of slope; to obtain information on housing and other factors of the living standards of the people and on the composition and nativity of families and the extent to which emigration or immigration affect the problem. It was intended that such information should furnish a basis which would be useful to the people of this region in forming judgments as to their present and future plans, and to public agencies needing information upon which to base action on such questions as public relief and the purchase of land for state or national forests.

The territory concerned in the present study included all the land in two contiguous magisterial districts in Knox County, comprising approximately 68,000 acres making up the entire drainage basin of Stinking Creek, one of the important tributaries of Cumberland River (Figure 1). This territory was selected because it presented a situation typical of many others in eastern Kentucky

in which a relatively dense population was undertaking to eke out a living chiefly by the cultivation of steep and eroded land. In addition to the Stinking Creek watershed, two areas in the county were chosen for an intensive study of the land utilization and

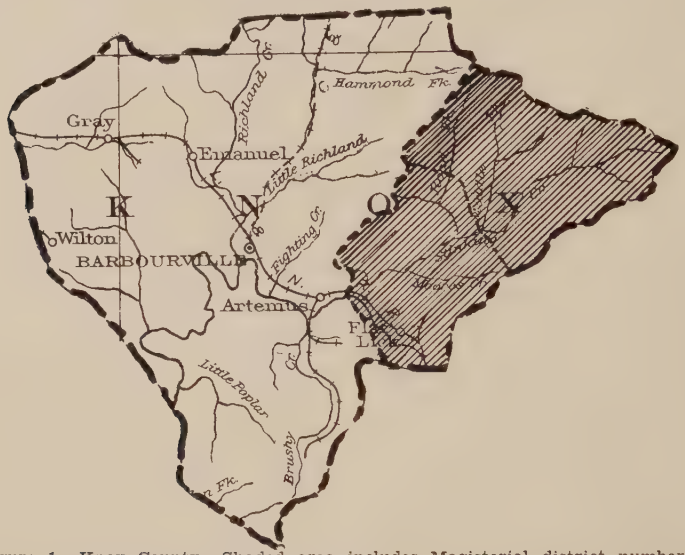

Figure 1. Knox County. Shaded area includes Magisterial district number three, near the Cumberland River, and district number four on the upper part of Stinking Creek. Land use and drainage data were obtained along the Cumberland River southwest of Barbourville and on Big Richland Creek north of Barbourville.

drainage problems of level bottom lands with particular reference to the possibilities of these lands in furnishing resettlement opportunities for families stranded on submarginal farms.

For the entire Stinking Creek area a land-use map was made based on inspection of the land by 10-acre blocks and showing the use to which the land was being put. The condition of representative farm houses including their size, type and location was determined. Family incomes and expenditures and the net spendable income were determined for each of 176 representative farm families. The data collected showed the cost of producing crops in terms of man labor, the cost of clearing land, and cycles of land use. The farm and family income data were for the farm year 1932 and the cost data for the years 1932 and 1933. Besides the study in the Stinking Creek watershed a further intensive study was made in two other areas in the county which included a large proportion of level creek and river bottom land.

KNOX COUNTY

Knox County occupies an area of approximately 356 square miles in the foothills of the Cumberland Plateau of the Appalachian Mountains. The Cumberland River traverses the southwestern part of the county. Except the narrow bottoms along the river and its tributary creeks, the land area of the county is made up largely of steep hills and narrow valleys formed by the wearing away of the Cumberland Plateau. The elevation of the land above sea level ranges from slightly less than 1,000 feet near the Cumberland River to 1500 feet on most of the hill tops. This study indicates that approximately 90 percent of the land has a slope of more than 15 feet in 100 feet distance and approximately 60 percent of all the land has a slope of 40 percent or more. Approximately 10 percent of the land of the county lies sufficiently level to permit intensive cultivation but much of this level land at present is unproductive because of poor drainage. Most of the level land has been cleared but approximately two-thirds of the hill land is in brush or woods. Practically all the land has been cut over. The brush land represents a new growth on land that has been cleared.

The total area of land in farms in Knox County reached a maximum of 199,218 acres in 1900. In 1930 there were 155,203 acres of land in farms and in 1935, 158,248 acres. Approximately 69.5 percent of the total land area of the county was in farms in 1935. The remaining 30.5 percent is largely land owned by lumber and mining companies and waste land.

The most important crop grown is corn. Annual legumes and grasses are cut for hay on most farms with level land. Small acreages of potatoes and garden products are grown mainly for home use. Most of the corn is grown on steep land that has been recently cleared. Approximately one-half of the cleared land is "lying out", having been cropped until it no longer yields enough to provide a return for labor. Corn yields range from 25 to 35 bushels per acre on newly cleared land to 5 to 15 bushels on land that has been cropped for 5 to 15 years. Hay is produced principally on the level bottom land along the creeks. Yields of hay usually range from ¾ to 1½ tons per acre. Most of the hillside land is too steep for the use of a mowing machine for harvesting and therefore very little hay is produced on this type of land.

The normal temperature in Knox County is suitable for most

crops commonly grown in the northeastern states. The average growing season is approximately 180 days and the average precipitation 50 inches, fairly well distributed thru the growing season.

Barbourville, the county seat, located near the center of the county, has a population of 2380. Corbin, a railroad center with a population of 8036 is located on the edge of the county but lies mostly in the adjoining county of Whitley.

TENURE STATUS AND CAPITAL INVESTMENT OF OPERATORS

Thirty-six percent of the 176 operators owned no land. Nineteen percent owned land and rented additional land and the remaining 45 percent farmed their own land. As would be expected, there was a considerable relationship between land ownership and the need for relief from public agencies. Fifty-seven percent of all the operators received such relief during the period to which the data of the study apply (March 31, 1932 to April 1, 1933). Seventy-seven percent of those who owned no land received relief aid while only 37 percent of the operators who farmed their own land received such aid.

The value of land and buildings averaged $1167, or about $18 per acre, for the 176 farms. The dwelling houses averaged $187 in value. The land and buildings of the operators who were full owners had a value of less than $1000, in a third of the cases; $1001 to $2000, in a fourth of the cases; and from $2001 to $3000, in a fifth of the cases. In only one case in eight was the value of the land and buildings more than $3000.

The farms averaged 63½ acres in total area. Twenty-four of the 176 farms were larger than 125 acres and 33 were smaller than 10 acres; 73 were smaller than 25 acres and 105 were smaller than 50 acres. Corn was the principal crop on these farms and averaged 9.7 acres for the 176 farms. Twenty-five of the farms had less than 5 acres of corn and 90 less than 10 acres. Only 16 of the farms had over 20 acres of corn.

There was an average of 9½ acres of bottom and well-lying land per farm, but more than a third of the operators had no such land and only about half of all the operators had as much as 5 acres of well-lying land.

The number of work animals averaged 1.1 head per farm. Forty-six of the 176 operators did not own a work animal, three owned one

work animal each, 43 owned two and only 8 owned more than two work animals each. There was an average of 1.7 milk cows per farm. One-tenth of the operators had no milk cows, about a third of the operators had one cow, and about a third of them two cows. Only 37 of the 176 operators had more than two cows.

One hundred and sixty-four of the 176 operators had one or more hogs. Only 76 operators had one or more brood sows. There was an average of 29 chickens per farm. Only two of the 176 families had more than 50 chickens, while 22 families had less than 10.

FARM RECEIPTS AND SPENDABLE INCOME

The meagerness of the incomes of these families is shown in Table 1. Because of the marked difference in the amount of level land and other resources, the 176 farms were divided into three groups consisting of 60 farms in the rough territory of the upper reaches of Stinking Creek, 55 farms in the lower Stinking Creek territory having better land resources and 61 other farms having for the most part land and other resources of an intermediate order. The gross receipts from crops and livestock averaged $58 per family which was little more than enough to pay current cash farm expenses without making allowance for any depreciation. Without the receipts from non-farming sources these families would have had practically no spendable income. The non-farming income

Table 1. Family receipts and spendable income for 176 farm operators on the Stinking Creek watershed, for the year ending April 1, 1933.

Item	Stinking Creek Watershed 176 farms	Upper Stinking Creek 60 farms	Lower Stinking Creek 55 farms	Other 61 farms
Receipts from crops	$ 17	$ 9	$ 30	$ 13
Receipts from livestock	41	28	72	25
All other receipts	53	35	80	47
Total receipts	$ 111	$ 72	$ 182	$ 85
Cash farm expenses	43	24	76	32
Net family income (spendable)	$ 68	$ 48	$ 106	$ 53
Family living from farm	147	117	194	133
Total family receipts	$ 215	$ 165	$ 300	$ 186
Total non-cash farm expenses	76	30	140	63
Family earnings	$ 139	$ 135	$ 160	$ 123
Number of persons in household	5.5	5.5	5.4	5.5

averaged $53 per family, more than a fourth of which came from work relief and direct relief.

The number of persons averaged 5½ per family and the net income available for spending averaged $68 per family. Twenty-four of the 176 farm operators had no spendable income after the current farm expenses were paid, 66 had from $1 to $50, 44 from $51 to $100, 28 from $101 to $150, and 14 had from $151 to $467. Adding to the $68 which was the average spendable income of the 176 families, the value of the things contributed by the farm to the family living gives total family receipts of $215. Subtracting from this item the non-cash items such as interest on the investment ($58), depreciation ($9) and decrease in feeds and supplies ($9) totaling ($76), leaves family earnings of $139 as an average for the 176 operators. The family earnings were less than $50 in a fifth of the cases, and less than $150 in two-thirds of the cases. In only one-fourth of the cases were the family earnings more than $200.

It is significant that the spendable income available for the 60 families living in the rugged upper Stinking Creek territory was $48 as compared with $106 for the families living in the more favorable lower Stinking Creek territory.

The total receipts averaged $111 for the 176 families. Of this total about half came from crops and livestock and about half from labor off the farm, store-keeping, school teaching, oil and gas leases, work relief and direct relief. Fifty-seven percent of the 176 operators received some aid from public relief agencies; 75 percent for the upper Stinking Creek group and 33 percent for the lower Stinking Creek group.

That the income per family in the lower Stinking Creek group was more than twice the amount for the upper Stinking Creek group is principally due to a larger income from crops and livestock in the former group. The chief crops sold were corn, sorghum, potatoes, and other garden products in the lower Stinking Creek group, while the chief sales for the upper Stinking Creek group were corn and potatoes. Poultry and dairy products, hogs and veal calves were the chief sources of livestock receipts for the lower Stinking Creek group, while poultry products and veal calves were the chief sources for the upper Stinking Creek group. The item "all other receipts" which included work relief, labor off the farm, income from oil and gas leases, etc., for the lower Stinking Creek group was

more than double the amount for the upper group. However, the receipts from work relief for the lower Stinking Creek group were less than half as great as for the upper group. Opportunities for part-time work off the farm for private employers were decidedly greater for the lower Stinking Creek group than for the upper group. The family spendable income is a significant measure of the results which farm operators are able to obtain from the resources at their command. As previously shown, the cash receipts derived directly from the farm were hardly sufficient to cover the cash farm expenses. In most cases, therefore, the ability of the family to have a cash income is largely dependent upon opportunities for acquiring income from non-farming sources. Such opportunities have been very greatly decreased since 1929. Furthermore, families that had previously moved away from this territory to engage in coal mining and other industrial occupations later returned because of the shutting down of the industries in which they had been employed. An important factor affecting opportunities for the sale of farm products raised in this territory, such as vegetables, poultry, eggs, milk and butter, was that the cessation or decline of opportunities for work in the local coal mines sharply reduced the buying power of these families during the period covered by this study.

FAMILY LIVING FURNISHED BY THE FARM

This study confirms the fact brought out in other studies made by the College of Agriculture in the Kentucky mountains that the well-being of families in this region is dependent in very large measure upon their producing an ample supply of foods for home use, especially poultry, dairy products and vegetables for summer use and storage for use after the growing season.

The value of the living furnished by the farm is shown in Table 2. The item averaged $147 for the 176 families, about 2½ times as much as the entire money income from crop and livestock sources. The value of family living furnished by the farm exceeded $150 for 74 of the 176 families and was less than $150 for 102 of the families. The money value of the use of the farm dwelling was put at 10 percent of the value of the dwelling and the item averaged $18 for the 176 families. The value of the dwelling house was less

than $100 in 78 of the 176 cases, less than $200 in 120 cases, and more than $200 in only 56 cases.

Table 2. Family living furnished by the farm.

Item	Values of			
	Food	Fuel	Use of dwelling	Total value
For families on Upper Stinking Creek	$ 107	$ 3	$ 7	$ 117
For families on Lower Stinking Creek	155	3	36	194
For all families	125	4	18	147

Food furnished by the farm for the family living averaged in value $125 for the 176 families[1]. The value of the item was less than $100 in 72 cases, $100 to $200 in 81 cases, and more than $200 in 23 cases. The item was 50 percent greater for the lower Stinking Creek families than for the upper Stinking Creek families.

Table 3. Farm expenses and family earnings for 176 farms, for the year ending April 1, 1933.

Item	Stinking Creek Watershed 176 farms	Upper Stinking Creek 60 farms	Lower Stinking Creek 55 farms	Other 61 farms
Depreciation	$ 9	$ 3	$ 17	$ 7
Decrease in feed and supplies	9	4	13	9
Interest on estimated value of investment	58	23	110	47
Total non-cash expenses	$ 76	$ 30	$ 140	$ 63
Current cash farm expenses	43	24	76	32
Farm expenses (total)	$ 119	$ 54	$ 216	$ 95
Average family earnings	$ 139	$ 135	$ 160	$ 123
Value of unpaid family labor other than the operator	$ 68	$ 48	$ 76	$ 79

FARM EXPENSES

The expenses incurred on the 176 farms are shown in Table 3. The chief cash farm expense items were taxes, hired labor, horse

1 Based upon the price of the same items of food in the year 1937 the total valuation would be about $250 or double the amount shown in table 2. The values used for the principal items of food furnished the family from the farm in the year 1932 were as follows:

Item	Unit	Value	Item	Unit	Value
Corn for bread	bushel	$0.50	Onions	bushel	$0.50
Corn (roasting ear)	dozen	.10	Cabbage	pound	.005
Potatoes	bushel	.50	Hens	each	.40
Sweetpotatoes	bushel	.50	Chickens (fryers)	each	.20
Turnips	bushel	.50	Hogs	pound	.04
Green beans	bushel	.50	Whole Milk	quart	.08
Apples	bushel	.50	Eggs	dozen	.09
Tomatoes	bushel	.50	Wood	cord	.25

shoeing, feeds and seeds. These totaled $43 as an average for the 176 operators, $76 for the lower Stinking Creek operators, and $24 for the upper Stinking Creek operators. The non-cash expense items for the 176 operators were $58 imputed as interest on the total investment in the farm, $9.00 depreciation on equipment, and $9.00 decrease in feed and supplies. Eighty-two of the 176 operators had cash farm expenses of less than $20 for the year. Forty operators had expenses ranging between $20 and $40, and 54 operators more than $40.

The value of the labor contributed by members of the farm family other than the operator averaged $68 for the 176 families.

LAND UTILIZATION

The two magisterial districts included in the land classification analysis comprise about a third of Knox County. Except for narrow bottoms along the river or main creeks, the land area in this territory is made up of steep hills. Ninety percent of the steep land has a slope of more than 25 degrees.

On a considerable acreage of this steep land, young trees, which in a few years would be large enough for saw timber, are constantly being destroyed to make way for corn patches. A few crops of corn on this land exhausts the limited amount of fresh organic matter and brings about erosion to the extent that the land will grow neither corn nor good timber. The re-cleared land in many cases is not sufficiently productive to yield more than 10 bushels of corn per acre in a normal season. Because of the steep and often rocky nature of the land only 1-horse plows can be used to break it and in a great many cases the entire cultivation must be done by hand. This means that the entire crop of one man is often limited to three to five acres, producing only 40 to 60 bushels for the entire area. This meager amount is much too small to furnish the family its quota of 25 bushels of meal for the year, and to feed a horse, a cow, 10 to 20 chickens and fatten a meat hog. Consequently the result is undernourishment for the family and few or no products to sell for cash with which to purchase clothing and other non-farm-produced necessities for the family.

Corn constituted approximately 68 percent of the acreage of all the land in harvested crops in the two magisterial districts making up the Stinking Creek area. Two-thirds of the corn is grown on

hillsides having slopes ranging from 10 to 40 degrees or more. The result of this type of cropping is that the hillsides have reached a stage of advanced erosion and very low productivity. The land in the upper reaches of Stinking Creek exemplifies particularly well the handicaps to which large numbers of farm families are subjected on rugged land thruout eastern Kentucky. The 60 farms in this group averaged only 39 acres in total area all of which except 2.4 acres were steep land very poorly adapted to the growing of corn, yet 21 percent of the total area of the hillside land was cultivated in corn (Table 4). In marked contrast the farms in the lower Stinking Creek area had eight times as much bottom land and only 3½ percent was cultivated in corn.

Table 4. Acreages and value of land and improvements per farm, Upper and Lower Stinking Creek. 1933.

Item	Upper Stinking Creek	Lower Stinking Creek
Number of farms	60	55
Average size of farm (acres)	39	92
Acres bottom land	2.4	20
Acres in crops	10.4	18.2
Acres in corn	8.3	11.5
Acres hillside corn	7.7	3.2
Value of dwellings	$ 70	$ 360
Value of land and improvements	471	2,186
Value of land and improvements per acre	12	40

Table 5 shows the labor requirements to produce corn on bottom land as contrasted with hillside land in the territory studied. The corn grown on the well-lying land was produced with 7.4 days of man labor per acre as compared with 16.2 days of labor per acre on the hill land. The average yield of corn on the well-lying land was considerably greater than that on the hill land. The corn on the bottom land yielded almost three times as many bushels per day of man labor as that on the hill land.

Table 5. Labor requirements to produce corn on bottom and hillside land, Stinking Creek. 1933.

Item	Bottom Land	Hillside Land
Number of farms	32	82
Total acres	237.5	504
Days man labor per acre	7.4	16.2
Bushels per acre	24.5	19.4
Bushels produced per day of man labor	3.3	1.2

A study of 28 fields on which crops were produced in 1932 indicates that most of the hillside land has been cleared only a short time and that it is capable of producing good yields for only a short period. Twenty-three hillside fields had been cleared or recleared for a period averaging five years. The range was one to 30 years. Usually after the second crop the fields lie out at least a year before being cropped again. It appears that an average of four cultivated crops may be expected from a field before it is allowed to grow up in brush or trees again.

The 23 hillside fields had an average slope of 31 degrees, the range in slope being from 18 to 55 degrees. The average area per field was 6.6 acres and the average yield of corn per acre was 21 bushels. Corn was the only crop produced on the 23 fields.

The five fields studied that were not on hillsides had slopes of three degrees or less. Three of these fields were in corn and two in soybeans. Two of the fields had been cleared for a period probably greater than 50 years and the other three 60, 60, and 50 years, respectively. The three fields in corn produced an average of 18 bushels per acre.

The study of the land use on the hillsides indicates a cycle of cropping, brush, and timber—that is, after the land is cleared, crops are produced for a few years, then brush is allowed to grow up and later develop into timber thus necessitating reclearing before the land can be cropped again. Cropping only was the characteristic practice on the bottom land. Having in mind that corn was the principal crop produced on both the hillside and bottom land a comparison was made of the total production of this crop during a cycle of hillside land use. Twenty-four years is probably an average length of cycle on the hillside land (Table 6). During this period an average of five crops of corn may be expected on land cleared for the first twenty-four year period and three crops on second clearing land for a similar period. Thus an average of four crops of corn may be expected on the hillside land. In the same number of years 12 crops of corn or other intertilled crop may be produced on the bottom land. Assuming average yields, the production of corn during the cycle on hillside land would average 77.6 bushels. Further assuming that soybean or cowpea hay is produced for two years of the four-year rotation on bottom land

and that the average yield per acre is 1½ tons, a total of 18 tons of hay would be produced during the 24 year period. Estimating the normal value of corn in this section at $1 per bushel and hay at $12 per ton the value of the total production per acre of corn and hay on the bottom land thru the 24 year period would be $495 or nearly $21 per year. At these same prices the total production per acre on the hillside land for the 24 year cycle would be $77.60 or a little over $3 per year. Thus for the bottom land almost four times this amount would be produced. The production of corn per 10-hour day of man labor would average 1.2 bushels for the hillside land and 3.3 for the bottom land.

Table 6. Cycles of land use on one acre of hillside and bottom land.

Year	Cycles of land use — 24 years		
	Hillside land		Bottom land
	1st clearing	2nd clearing	4-year-rotations
1	Corn	Corn	Corn
2	Corn	Idle	Corn
3	Idle	Corn	Hay
4	Corn	Idle	Hay[1]
5	Idle	Corn	Corn
6	Corn	Idle	Hay
7	Idle	Idle	Corn
8	Corn	Brush	Other crop
9	Idle	Brush	Corn
10	Brush	Brush	Corn
11	Brush	Brush	Hay
12	Brush	Brush	Hay
13 to 24	Growing timber	Growing timber	Same as above
Total corn acreage	4 acres (ave.)		12 acres
Estimated yield per acre	19.4 bus.		24.5 bus.
Total corn production	77.6 bus.		29.4 bus.
Total labor required	64.8 days		88.8 days
Production per day of man labor	1.2 bus.		3.3 bus.

1 Or other crop.

COST OF CLEARING LAND

Since only an average of four crops may be produced on a hillside field before it is allowed to go back to brush or trees, the labor and equipment necessary to clear or reclear an acre of land is an important item. Man labor is the principal item of cost in clearing land. The use of horse labor and any equipment other than a crosscut saw, axe and mattock is insignificant. The land is usually cleared in the late fall or early spring before time for plowing.

The man labor required per acre ranged from 5 to 25 ten-hour days.

The average man labor required for clearing 118 acres on 24 farms in the year 1933 was 10 days per acre. Since many fields used for corn are cleared, cropped a few years, then allowed to grow up in brush and later trees until cleared again, the labor for clearing land represents on the average a considerable proportion of the total labor necessary for producing corn on hillside land.

LAND CLASSIFICATION

A major purpose of this study of land utilization in Knox County was to determine the location and extent of areas of land adapted to more or less intensive use and to suggest plans for their best utilization and development.

At present most of the land in Magisterial Districts three and four of the county is owned by farmer operators. However, a considerable portion is owned by coal companies or speculators in mineral lands, particularly in District four. Altho there are no coal mining operations in these districts, except a small mine at Ely near the Cumberland River and scattered farm mines for local use, a large proportion of the farm owners have sold the right to mine coal on their farms. The coal right usually includes the right to use a limited area for operation of a mine and to use the timber on the farm for mining purposes[1]. A number of farm owners have leased or sold the oil rights to their land. Some of the oil leases have been cancelled or terminated[2].

BASIS OF LAND CLASSIFICATION

Many factors are related to the intensity of use to which land is adapted and are significant as bases of classifying it from the standpoint of the intensity of its use. The most important of these factors are present use, soil, topography, climate and distance to

1 The following is a typical paragraph included in the deed for sale of coal:
"Second party is granted necessary right-of-way on the surface of said land to mine and remove all said mineral, and room for tipples, entries, shafts, pits, tramways, roads and passageways, and also enough small unmerchantable timber from the surface of said land to supply the mines with caps, props, and with mine timbers."

2 A typical oil and gas lease specifies the acreage and length of lease and also includes the following:
"Lease for purpose of mining and operating for oil and gas, and of laying pipe lines and building tanks, stations, telephone, telegraph and electric power lines, houses for gates, meters and regulators with all other rights, privileges, appliances and structures necessary incident and convenient for the operation of this land alone and conjointly with neighboring lands."

market. The character of the soil influences the kind of crops grown, the quality of products raised, and the crop yield. Erosion is a serious problem where the slopes are steep. Topography as well as distance to market influences marketing costs. Climate in-

Figure 2. Magisterial districts three and four, showing land classes. Land Class I, 4,798 acres; land class II, 52,603 acres; land class III, 10,359 acres; total land area, 67,760 acres.

fluences the kind of crops grown, the quality of products and crop yields. The crops grown, crop yields, the quality of products produced and marketing costs have an important influence on farm incomes. The income from farming over a period of years influences every phase of life of the people of an agricultural area, in-

cluding their ability to keep their buildings and improvements in good condition and to provide by taxation desirable social services such as schools and roads.

The principal bases used in classifying the land in this study were topography, soil, the present use of the land and the condition of buildings. The land was divided into three classes according to the intensity of present and probable future uses (Figure 2).

LAND CLASSES

Land Class I includes a large proportion of woods and idle land (approximately 90 percent) and most of the farms have been abandoned. It is primarily adapted to forestry and recreational uses.

Land Class II includes land now largely in farms but unsuited to agricultural use. Many of the farms have been abandoned, but considerable farming is being done. The crops grown, the topography, the soil, extent of erosion, and the size and condition of buildings indicate that, in general, the land is better adapted to forestry or recreational use than farming. The woodland, brush, and idle land probably averages about sixty percent of the class.

Land Class III is fairly good agricultural land. As long as there is income from industry, such as lumbering and coal mining within the area, or from other sources, the well-lying land will probably continue to be used for subsistence and part-time farming.

METHOD OF CLASSIFYING THE LAND

The use of the land was determined by a land-use map covering all of Magisterial Districts three and four in Knox County. In preparing the land-use map, a United States Geological Survey Topographic map was photographed and ruled into squares of approximately 10 acres each (Figure 3). Field workers then went over the land and noted in each square the predominant use of the land as woodland, brush, corn, hay, pasture, or some other use.

If the land in a square was being used for more than one purpose, the area of each minor use was estimated by the enumerator and the estimate recorded in field notes. The relation of the 10-acre square to the streams, roads, and topographic features was used by the enumerator to determine location, distance and direc-

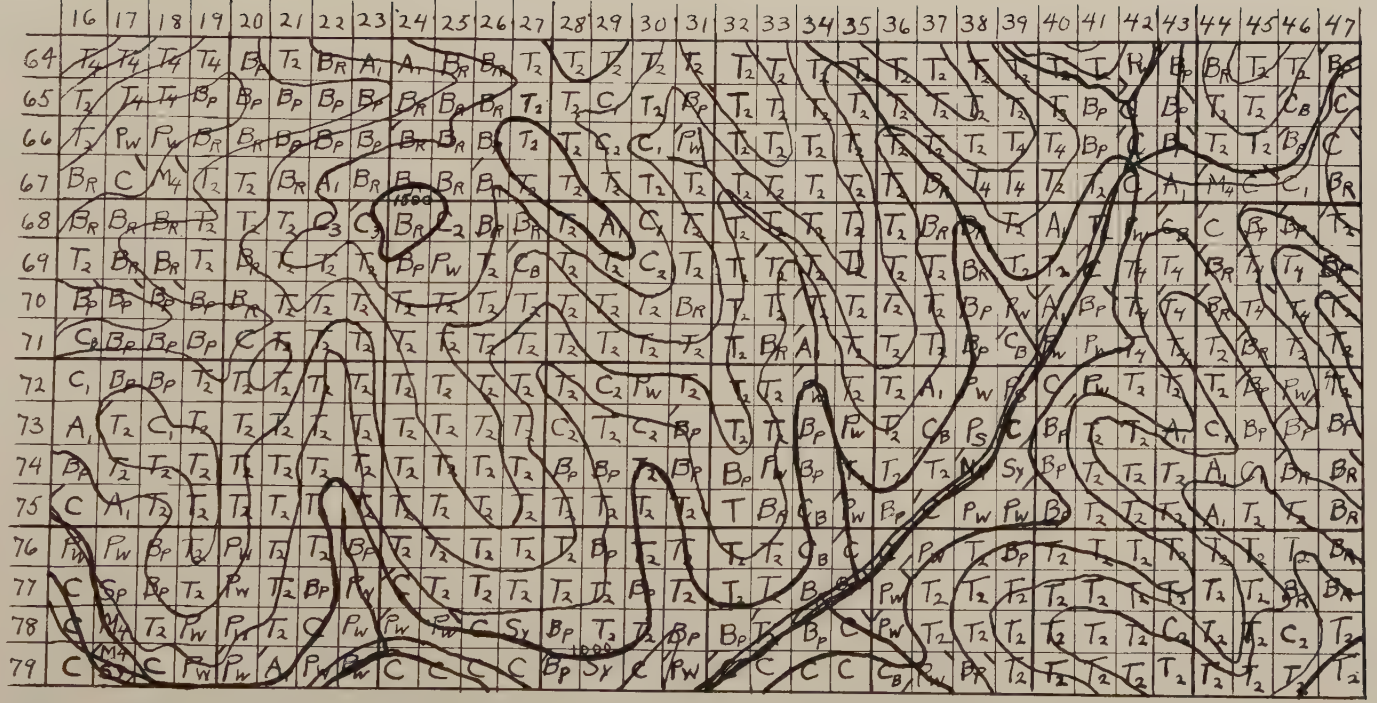

Figure 3. Section of Stinking Creek watershed cover map showing ten-acre squares. Contour lines and streams are shown as solid lines.

tion. Considerable pacing of distance was also done and estimates were often checked with farmers.

Symbols for the land cover are as follows:

A1—Cleared land idle one year.
As—Cleared land idle several years.
Bp—Brush land pastured.
Br—Brush land not pastured.
C —Corn on level land.
C1—Corn, first year clearing.
C2—Corn, second year clearing.
C3—Corn on stumpy land.
Ca—Corn on recleared land.
Cb—Corn on clean hillside land.
Dv—Rural residential area.
G —Garden or truck.
Iv—Land plowed but not cropped.
K —Rye for hay or pasture.
M2—Clover and clover and timothy.
M3—Timothy.
M4—Old meadow.
M5—Wild grass hay.
O —Orchard.
P —Seeded pasture.
Pw—Wild grass and weed pasture.
S —Potatoes.
T —Virgin timber.
T2—Cutover timber land.
T3—New growth timber on cleared land.
T4—Cutover timber land damaged by fire.
W —Wheat.

The condition of the farm houses including size and type of structure, was noted and each house located in the 10-acre square to which it belonged (Figure 4). The houses were classified into five groups according to condition: good, fair, poor, dilapidated, and unclassified.

USE OF LAND IN DIFFERENT CLASSES

The total area of Magisterial Districts 3 and 4 in Knox County is 67,760 acres. Of this total area, Class II comprised 52,603 acres

or nearly five-sixths of the total. The area of Class III land was 10,359 acres and of Class I land, 4,798 acres (Table 7).

Figure 4. Magisterial districts three and four, showing location of houses and land classes. There were no occupied houses in land Class I. In land Class II there were 10 occupied houses per 1,000 acres of land and in land Class III there were 29 occupied houses per 1,000 acres. The land in Class III included the unincorporated villages of Flat Lick and Himyar. The location of these villages is indicated by the rows of houses near the Cumberland River in the lower left-hand corner of the map.

There was a wide variation in the use of the land in the three land classes. In Class I for example 98 percent of the total area was in woodland (including brush land) and idle land as compared with 71 percent in Class II and 31 percent in Class III (Table 8). Approximately two percent of all the area in Land Class I was in pasture, 18 percent in Class II and 33 percent in Class

III. Corn and hay were the principal field crops. There was practically no corn in Class I, eight percent of the total area was in corn in Class II and 20 percent in Class III. Garden and miscellaneous crops amounted to 12 percent of the total area in Land Class III compared with one percent in Class II and practically none in Class I.

Table 7. Acres of land used for different purposes in each of three land classes, Stinking Creek watershed. 1933.

Use of land	Acres in land classes			
	I	II	III	Total
Woodland and idle*	4690	37367	3172	45229
Pasture†	83	9669	3404	13156
Hay	—	561	451	1012
Corn	24	4352	2094	6470
Garden and miscellaneous	1	654	1238	1893
Total all uses	4798	52603	10359	67760

* Woodland occupies more than three-fourths of this land on the average.
† Seeded pasture occupies only 20 acres of the total land in pasture.

The acreage by land classes for the uses designated as woodland and idle, total pasture, total hay, total corn, garden and miscellaneous in Table 7 is shown in Table 9. The acreage in woodland is approximately 91 percent of the total area in Land Class I, 54 percent in Class II and 18 percent in Class III.

Table 8. Percent of land used for different purposes in each of three land classes, Stinking Creek watershed. 1933.

Use of land	Percent in land classes			
	I	II	III	Total
Woodland and idle[1]	97.75	71.04	30.62	66.75
Pasture[2]	1.73	18.38	32.86	19.42
Hay	—	1.07	4.35	1.49
Corn	.50	8.27	20.22	9.55
Garden and miscellaneous	.02	1.24	11.95	2.79
Total all uses	100.00	100.00	100.00	100.00

1 Idle land occupies only 4 percent of the land; brush land, 13 percent.
2 Seeded pasture amounted to less than one-tenth of one percent of the land.

Most of the land used for pasture was brush in Classes I and II and about equally divided between brush and weed pasture in Class III. The hay harvested was principally old meadow (mostly redtop) in Class II and approximately equally divided between grass hay and soybeans and cow-peas in Class III.

The corn acreage was principally hillside corn in Land Classes I and II and bottom land corn in Class III. Garden and truck crops include home garden, truck and potato patches. The item "Miscellaneous" includes the villages of Flat Lick and Himyar, roads, railroads, orchards, oats, sorghum, and the portion of the area occupied by waste land and the Cumberland River.

Table 9. Acres of land used for different purposes in each of three land classes, Stinking Creek watershed. 1933.

Use of land	Acres in land classes			
	I	II	III	Total
Woodland	4,370	28,404	1,833	34,607
Brush land	280	7,668	629	8,577
Idle land	40	1,295	710	2,045
Total woods and idle	4,690	37,367	3,172	45,229
Brush pasture	67	6,557	1,616	8,240
Weed pasture	16	3,112	1,768	4,896
Seeded pasture	—	—	20	20
Total pasture	83	9,669	3,404	13,156
Soybeans and cowpeas	—	80	211	291
Clover	—	11	10	21
Timothy or redtop	—	57	35	92
Old meadow	—	330	165	495
Wild grass hay	—	83	30	113
Total hay	—	561	451	1,012
Hillside corn	24	3,612	529	4,165
Bottom land corn	—	740	1,565	2,305
Total corn	24	4,352	2,094	6,470
Garden and truck[1]	1	433	257	691
Miscellaneous[2]	—	221	981	1,202
Total garden, truck and misc.	1	654	1,238	1,893
TOTAL ALL USES	4,798	52,603	10,359	67,760

1 Includes garden, truck and potato patches.
2 Includes village of Flat Lick, roads, railroads, orchards, oats, sorghum and Cumberland River.

CONDITION OF FARM HOUSES

The condition of the farm house was one of the factors used in dividing the land of the Stinking Creek area into the three land classes. "Condition" refers to size and type of structure as well as the state of repair and age of the house. There were 304 houses

in Land Class III, 591 in Class II and two unoccupied houses in Class I. Since there were no occupied houses and only two unoccupied houses in Class I the analysis of housing data that follows includes only the houses in Land Classes II and III (Table 11).

Table 10. Acres of land used for different purposes in each of three land classes, Stinking Creek watershed. 1933.

Use of land	Acres in land classes			
	I	II	III	Total
Woodland	91.08	54.00	17.70	51.07
Brush land	5.84	14.58	6.07	12.66
Idle land	.83	2.46	6.85	3.02
Total woods and idle	97.75	71.04	30.62	66.75
Brush pasture	1.40	12.47	15.60	12.16
Weed pasture	.33	5.91	17.07	7.23
Seeded pasture	—	—	.19	.03
Total pasture	1.73	18.38	32.86	19.42
Soybeans and cowpeas	—	.15	2.04	.43
Clover	—	.02	.09	.03
Timothy or redtop	—	.11	.34	.13
Old meadow	—	.63	1.59	.73
Wild grass hay	—	.16	.29	.17
Total hay	—	1.07	4.35	1.49
Hillside corn	.50	6.87	5.11	6.15
Bottom land corn	—	1.40	15.11	3.40
Total corn	.50	8.27	20.22	9.55
Garden and truck[1]	.02	.82	2.48	1.02
Miscellaneous[2]	—	.42	9.47	1.77
Total garden, truck and misc.	.02	1.24	11.95	2.79
TOTAL ALL USES	100	100	100	100

1 Includes garden, truck and potato patches.
2 Includes village of Flat Lick, roads, railroads, orchards, oats, sorghum and Cumberland River.

Houses classified as good had at least three rooms, a fairly good coat of paint, stone or concrete block foundation, roof in good condition and in other ways had the appearance of being in good state of repair. The houses in this class were either frame, brick or stone (Figure 5).

Houses classified as fair had at least three rooms, tightly constructed, a substantial foundation and were in a fairly good state of

repair. These houses were usually of boxed construction with strips over the boxing, or of rough frame construction and unpainted. A number of the houses in this class were frame, brick or stone in a poor state of repair (Figure 6).

Table 11. Condition and use of houses in land classes II and III. 1933.

	Land class II Number		Land class III Number	
Occupied houses				
Condition of house				
Good	21		31	
Fair	118		108	
Poor	313		134	
Dilapidated	82		17	
Unclassified	12		7	
Total number occupied houses		546		297
Unoccupied houses				
Condition of house				
Good	0		0	
Fair	0		0	
Poor	14		1	
Dilapidated	28		6	
Unclassified	3		0	
Total number unoccupied houses		45		7
TOTAL all houses		591		304

Houses classified as poor usually consisted of only two rooms, with four windows or fewer and were in an average state of repair. Most of them were of boxed or log construction with rough stone or wood foundation and clap-board roof. The openings between the boards or logs were closed with strips or clay. A few were of frame or better type of construction but in poor or dilapidated condition due to age or want of care (Figure 7).

In the class of dilapidated houses many had only one or two rooms and were of log or rough boxed construction with nothing or only rough boards over the openings between the logs or rough boards. Many had no windows. A few were of stripped boxing or frame construction but because of age were included in this class (Figure 8).

In Land Class II, 23.5 percent of all houses were classified as good or fair and 45.7 in Class III (Table 12). None of the houses in good or fair condition in any land class were unoccupied.

In Land Class II, 66.9 percent of all houses were classified as poor or dilapidated occupied houses and 49.7 in Class III. The unoccupied houses classified as poor or dilapidated totaled 7.1 percent of all houses in Land Class II and 2.3 percent in Class III.

Figure 5. A typical farm house classed as good. Six percent of all the occupied houses in the area were in this class.

Figure 6. A typical farm house classed as fair. Twenty-seven percent of all the occupied houses in the area were in this class.

Figure 7. A typical farm house classed as poor. Fifty-three percent of all the occupied houses in the area were in this class.

Figure 8. A typical farm house classed as dilapidated. Twelve percent of all the occupied houses in the area were in this class.

The total of all houses classified as poor or dillapidated was 74 percent in Land Class II and 52 percent in Class III. In Land Class II, 2.5 percent of all houses were unclassified and 2.3 in Class III.

An analysis was made of the age, number of rooms, present and replacement value of 188 farm houses on the Stinking Creek watershed by condition of house. The houses classified as good were valued at almost four times as much as those classified as poor (Table 13), and the replacement value was more than double that of the houses classified as poor. The average age of the "fair" and "poor" houses was twice that of the "good" houses and the age of the "dilapidated" houses was nearly three times that of the "good"

houses. The houses classified as dilapidated had approximately one room less per house than those classified as good and fair.

Table 12. Percentage distribution of condition and use of houses in land classes II and III. 1933.

	Land class II		Land class III	
Occupied houses				
Condition of house				
Good	3.5		10.2	
Fair	20.0		35.5	
Poor	53.0		44.1	
Dilapidated	13.9		5.6	
Unclassified	2.0		2.3	
Total percent houses occupied		92.4		97.7
Unoccupied houses				
Condition of house				
Good	0.0		0.0	
Fair	0.0		0.0	
Poor	2.4		0.3	
Dilapidated	4.7		2.0	
Unclassified	0.5		0.0	
Total percent houses unoccupied		7.6		2.3
All Houses		100.0		100.0

A classification of the farm houses by type of construction revealed that approximately one-half of the 188 houses were of the box type. The average present value of the frame houses was approximately eight times the value of the log houses and more than three times the value of the boxed houses (Table 14). The average replacement value of the frame houses was more than eleven times that of the log houses and over three times the replacement value of the boxed type of houses. The average age of the frame houses was practically double the age of the log houses and

Table 13. Average age, size, present and replacement value of farm houses on the Stinking Creek watershed, by condition of house. 1933.

Condition of house	Number of houses	Present value of dwelling	Replacement value	Age in years	No. of rooms
Good	49	$ 342	$ 476	11.9	3.7
Fair	69	200	362	21.0	3.7
Poor	57	94	213	23.8	3.2
Dilapidated	13	18	107	34.5	2.8
Total	188	$ 192	$ 329	20.4	3.5

more than one and one-half times the age of the boxed houses. The facts of the study indicate a trend toward the construction of more boxed houses in recent years. This is probably due to the lower cost of construction for this type of house and the fact that the lumber needed for boxed houses was more readily available locally than the lumber needed for the frame type of construction. The average number of rooms in the frame houses was more than double the number in the log houses.

Table 14. Average age, size, present and replacement value of farm houses on the Stinking Creek watershed, by type of house. 1933.

Type of construction	Number of houses	Present value of dwelling	Replacement value	Age in years	No. of rooms
Log	16	$ 45	$ 54	13.9	1.9
Boxed	90	107	176	16.0	3.1
Frame	68	351	605	25.7	4.4
Other[1]	14	138	287	30.1	3.3
Total	188	$ 192	$ 329	20.4	3.5

1 Log houses with boxed or frame additions.

A classification of the houses by the number of rooms showed that almost one-third of them had only one or two rooms, and about half three or four rooms (Table 15). Forty-two of the 188 houses had five or more rooms.

Table 15. Average age, size, present and replacement value of farm houses on the Stinking Creek watershed, by size of house. 1933.

Number of rooms	Number of houses	Present value of dwelling	Replacement value of dwelling	Age in years
1	3	$ 26	$ 27	1.3
2	48	46	76	15.0
3	59	123	207	18.4
4	36	188	346	20.3
5	22	451	698	22.3
6 or more	20	496	902	40.2
Total	188	$ 192	$ 329	20.4

THE FARM FAMILY

A further analysis of the housing accommodations was made according to the age of the farm operator. About 28 percent of these families had one person or less per room, 35.6 percent had from 1.1 to 2 persons per room, 25 percent had from 2.1 to 3.0 persons per room and 11.7 percent had 3.1 or more persons per room

(Table 16.) The number of persons per room was about equally distributed among the different age groups except in the group of operators under 24 years of age and in the group over 54 years. Of the 13 operators less than 25 years of age, there were none with more than two persons per room. In the group of operators over 54 years of age, there were 51 families and only 11 of these families had more than two persons per room.

An analysis was made of the different locations where the 176 farm operators, whose farm business was analyzed, had lived. One hundred and seventy-two of the 176 reported their places of birth. Of this number 160 were born in Knox County and 12 outside the county.

Table 16. Number of persons per room in 180 houses on the Stinking Creek watershed. 1933.

Age of operator (years)	Number of houses	Persons per room			
		1 and less	1.1 to 2.0	2.1 to 3.0	3.0 and over
0 to 24	13	3	10	0	0
25 to 34	36	8	11	12	5
35 to 44	39	6	14	14	5
45 to 54	41	8	14	13	6
over 54	51	25	15	6	5
Total	180	50	64	45	21

OCCUPATIONAL EXPERIENCE OF FAMILY HEADS

One hundred twenty-nine, or 73 percent, of the 176 farm operators had worked off the farm and 48 percent of the 176 farm operators had left the farm as a place of abode, for work, since 1920.[1] Most of the operators worked in local mining centers or in northern industrial areas. The ratio of the operators who had worked off the farm to those who had never worked off the farm was about the same in each of the three sub-groups (Table 17.) Practically all those who had never lived and worked away from the farm had received income for other than farm work while living on the farm.

One hundred of the 176 farm operators received relief from the federal government in 1933. Seventy-five percent of this number had worked off the farm. Assuming that relief was being ad-

1 Operators receiving income from labor off the farm while living on the farm were not included.

Table 17. Number of farm operators on the Stinking Creek watershed who had worked off the farm. 1933.

Number of farm operators	Stinking Creek watershed 176 farms	Upper Stinking Creek 60 farms	Lower Stinking Creek 55 farms	Other 61 farms
Who had never worked off farm	47	15	14	18
Who had worked off farm	129	45	41	43
Who had worked off farm since 1920	84	31	27	26
Who received relief in 1933	100	45	18	37
Who had worked off farm and received relief in 1933	75	34	16	25

ministered in a rational manner in this area, it appears that the relief problem was largely caused by the "back-to-the-farm" movement from industrial centers, the decrease in income thru depletion of the merchantable timber, decrease in fertility of the land, failure of local industries employing farm labor and the large natural increase in population.[1] Continued depletion of the farm land and the remaining timber resources appears inevitable as long as this situation remains. If these conditions continue, and if employment or relief are not provided, poverty and squalor may be expected for many years to come (Figures 9 to 12.)

MIGRATION FROM KNOX COUNTY

In addition to the movement away from the farm and a subsequent return as enumerated in Table 17, a considerable number have moved away and remained away. Calculations made from the data on population of the U. S. Census and the U. S. Division of Vital Statistics show the amount of migration that took place during the 20-year period, 1910 to 1930. The net migration[2] from Knox County for the period, 1910 to 1920, was estimated at 5300 persons or approximately 24 percent of the 1910 population. For the period, 1920 to 1930, the net migration was estimated at 3800

1 The index of natural increase for the rural farm population of Knox County was 193 in the year 1930. The index of natural increase is the number of children under five years of age expressed as a percentage of the number necessary to maintain a stationary population, assuming no changes in population due to migration. The index of natural increase for the rural farm population of the U. S. is 148. An index of 100 is necessary to maintain a stationary rural farm population assuming no migration.

2 Net migration is the number of people moving out of the county minus the number of people moving into the county during the same period of time.

persons, or approximately 16 percent of the 1920 population.[1] The larger net migration out of the county before 1920 was principally due to the rapid expansion of coal mining developments in neighboring counties, particularly in Harlan County. A large proportion of those who left Knox County, especially the young people, moved out of the area and in many instances out of the state.[2]

Figure 9. Destroying the potential cash crop to grow the subsistence crop (corn). Knox County, 1933.

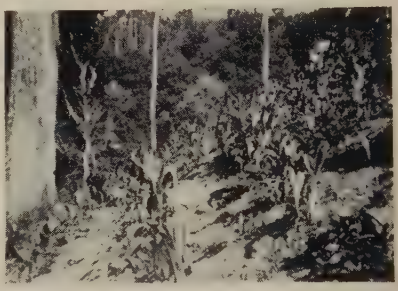

Figure 10. The two principal competing crops on hillside land. Trees are the potential cash crop. Corn is the subsistence crop. Knox County, 1933.

Figure 11. Plowing the "old field" for corn. A day of man labor produces a bushel of corn on hillside land. Knox County, 1933.

Figure 12. The "old field" erodes severely after the second crop. Hillside land Knox County, 1933.

1 The calculations for migration during the period, 1920 to 1930, were obtained from the "Study of Population Redistribution" made by Dr. C. W. Thornthwaite.

2 The number of sons and married daughters living away from home in 1928 was obtained for 203 farm families in Laurel County, an adjacent county to Knox County. The number of sons and married daughters away was 178 and 175, respectively, a total of 353. Their locations by areas were Laurel Co. 42.8 percent, another state 29.2, outside Laurel Co. in Mountain Area 14.7, an delsewhere in Kentucky 13.3 percent. A larger percentage of married daughters were living in Laurel Co. than the sons and a larger percentage of the sons were in another state than the married daughters. The occupation of the sons away from home were farmers 28.8 percent, laborers 24.3, professional services 17, tradesmen 12.4, public service 11.3, and merchant or dealer 6.2 percent. The occupations of the husbands of married daughters were farmers 54.7 percent, laborers 23.5, public service 10, tradesmen 5.3, professional services 4.7 and merchant or dealer 1.8 percent. U. S. Department of Agriculture Technical Bulletin No. 289.

According to the U. S. Census of 1930, the total population of Magisterial District No. 3 was 2851 persons and that of District No. 4, 1924 on April 1, 1930, a total of 4775 for the two districts (Table 18). This was 63 persons per square mile in District No. 3 and 33 per square mile in District 4. The unincorporated villages of Flat Lick and Himyar are located in District 3. The rural farm

Table 18. Population by sex and color in Magisterial Districts[1] 3 and 4 and in Knox County.[2]

Area	Total population	Sex		Color	
		Male	Female	White	Negro
District 3	2,851	1,501	1,350	2,717	134
District 4	1,924	1,003	921	1,924	0
Knox County	26,266	13,414	12,852	25,671	595

1 Districts 3 and 4 constitute the Stinking Creek watershed.
2 U. S. Census, 1930.

population[1] was 1934 in District 3, or 43 persons per square mile. District No. 4 includes the larger part of the rough Upper Stinking Creek Area with the entire population classed as rural farm. According to the U. S. Census of 1935 the rural farm population in the two magisterial districts increased 21 percent during the five-year period from 1930 to 1935. Approximately one-third of the increase was due to the return to the area from mining and industrial centers.

The greater part of the land in Eastern Kentucky unsuited to agriculture is adapted either to forestry or recreational purposes or both. Land suited to forestry would yield not only timber but also indirect advantages in the form of opportunities for hunting, fishing and other recreational privileges. Forestation would also improve the appearance of the country side, and be helpful in the protection of streams, the control of floods and the prevention of soil erosion.

On account of the long period between the planting of trees and harvesting of forest products, the enterprise should be handled on a large scale as a corporate, state or national project. This is true particularly of large contiguous areas which are unsuited to agricultural use. There is probably very little land in Eastern Kentucky that cannot be put to some useful purpose. A rational

1 Rural farm population means people living on farms in rural territory.

program for the use of land in this area should include the forestation and reforestation of land adapted primarily to forest use.

In regions where conditions are similar to those in the Upper Stinking Creek Area, very little money is available for new buildings or repairs to present buildings. If no new capital is brought into such areas, the depreciation of present improvements will eventually force the complete abandonment of most farms or a sinking of the people to greater depths of poverty. In such areas if schools and roads are furnished, they must be paid for with taxes collected elsewhere. Farm fire insurance companies must charge higher rates to clients elsewhere if insurance is to be furnished in such areas as this and losses incurred by agencies lending money to farmers must be borne by borrowers on more productive land.

ANALYSIS OF TWO REPRESENTATIVE AREAS OF WELL-LYING LAND

In addition to the analysis of the land resources in the two magisterial districts constituting the Stinking Creek watershed, a land-use analysis was made for two representative areas in Knox County having more well-lying land than the average for the Stinking Creek area. These two areas are located in the Cumberland River valley and in the valley of Big Richland Creek, a tributary of Cumberland River, an aggregate of about 18,000 acres. This phase of the study was intended to throw light on the possibilities of such land for furnishing a living for its operators and especially its possibilities for affording resettlement opportunities for families living on the rough lands of this and other eastern Kentucky Counties.

Big Richland Creek Valley Area. This area consisted of a block of 14906 acres along Big Richland Creek, constituting all the land of 165 contiguous farms, being practically all the farms on that creek. The acreage owned per farm averaged 90 acres, ranging from 3 to 300 acres. The number of farms less than 50 acres was 37, from 50 to 99 acres 65, from 100 to 149 acres 34, from 150 to 199 acres 14, and from 200 to 300 acres 15 farms. The analysis showed that 2556 acres or only 17 percent of this acreage consisted of level land. Of this, 2272 acres was bottom land and 284 acres

level upland.[1] Twelve thousand three hundred forty-two acres, or 83 percent, of all the land in these farms was hillside land. Of this, 11,463 acres or 93 percent was steeper than 10 degrees.

As a ten-year average the yield of corn on the bottom land was 24 bushels per acre, on the level upland, 22 bushels, on the hillside land of less than 10 degrees slope, 20 bushels, and on hillsides steeper than 10 degrees, 16 bushels. The steep hillside land was cropped mostly in corn in a much longer rotation than the level or rolling land. The 165 farms averaged 90.3 acres total area, 13.75 acres bottom land, 1.75 acres level upland, 69.5 acres of land steeper than 10 degrees and 5.3 acres of hillside land of less than 10 degrees slope.

For the 165 farms in the area studied, 1046 acres or 41.6 percent of the bottom land is in need of drainage (Table 19). The average farm in the area has nearly 14 acres of bottom land and 6.3 acres of this is in need of drainage. The acreage of bottom land per farm for the 55 farms on Lower Stinking Creek averaged 20 acres. About nine-tenths of the land needing drainage is cleared and two-thirds was in crops in 1933. Some of the land not cropped is so wet under present conditions that it is not worth while to try to raise crops, while some of it is in pasture grasses and can be grazed during the summer. Some pasturage can also be had during the summer from a portion of the uncleared land. The productivity of most of this land would be greatly increased by adequate drainage. Usually satisfactory drainage program should include a number of farms.

In Table 19, the farms in the Big Richland area are grouped according to the amounts of bottom land on the farm. It should be noted that as the amount of bottom land increases, the percent that needs drainage increases materially. No doubt this is partly because farms with small amounts of bottom land are often located higher up on the creek and on its tributaries, where the valley is narrower and hence less likely to need drainage, while farms with larger amounts of bottom land are nearer the mouth of the stream where the valley is wider and more nearly level and where the current is slow and the stream bed meanders. It is also partly because, with a larger amount of bottom land, the farmer finds it less urgent

1 Level upland, in this bulletin, is all upland that can be planted in row crops and plowed both ways without causing serious erosion. Usually this land has a slope of three degrees or less.

to make the best use of all his bottom land and is therefore less interested in spending the time and money necessary to do the needed draining. It should be noted however, that very little concerted effort had been made to drain the bottom land in this area up to the time of the study. Individual farmers had done some work on their own farms when the main stream bed was deep enough and near enough to take the water off.

Table 19. Relation of bottom land per farm to the amount of land needing drainage, Big Richland Area. 1933.

Bottom land per farm		Number of farms	Percent of bottom land needing drainage	Average width of bottom land (yards)
Range Acres	Average Acres			
0 to 9.9	4.3	90	35.6	49
10 to 19.9	13.1	36	35.9	139
20 to 29.9	23.3	17	55.4	239
30 to 39.9	32.7	8	44.1	86
40 and over	53.6	14	55.0	256
All farms	13.7	165	46.2	136
0 to 19.0	6.8	126	36	108
20 and over	36.1	39	52	207

In Table 20 is shown the relation of the amount of bottom land per farm to the amount of land per farm needing drainage and the degree of development of the land needing drainage. On the whole, as the amount of bottom land per farm increased, the land needing drainage, both cleared and not cleared, increased. Farms with less than 20 acres of bottom land had only 1.5 percent of bottom land

Table 20. Relation of the amount of bottom land per farm to the use made of land needing drainage, Big Richland Area. 1933.

Bottom land per farm		Number of farms	Percent of bottom land needing drainage	
Range Acres	Average Acres		Not cleared	Cleared
0 to 9.9	4.3	90	1.3	34
10 to 19.9	13.1	36	1.7	34
20 to 29.9	23.3	17	2.9	53
30 to 39.9	32.7	8	4.4	40
40 and over	53.6	14	5.6	49
All farms	13.7	165	3.3	43
0 to 19.9	6.8	126	1.5	34
20 and over	36.1	39	4.4	48

not cleared and needing drainage, and 34 percent of bottom land cleared and needing drainage, while farms with 20 acres or more of bottom land had 4.4 percent of bottom land not cleared and needing drainage, and 48 percent of bottom land cleared and needing drainage. Approximately three-fourths of the 165 farms had less than 20 acres of bottom land, and more than half had less than 10 acres per farm.

On the 165 farms studied in the Big Richland area there were 266 acres of corn on land which is usually overflowed in summer. In taking the schedule, the farmer was asked in each case, how many total crop failures were experienced in 10 crops? The weighted average number of total crop failures experienced out of 10 crops as a result of drowning was 1.87 for the 266 acres. For the land in corn in 1933, the expected average annual loss amounts to 1,074 bushels or 4 bushels for each acre planted.

A total crop failure on land which is flooded in winter only is rare and consequently the average annual loss due to crop failure is negligible. It should be recognized, however, that the winter flooding prevents the production of all crops except spring-planted ones such as corn, sorghum, cowpeas, soybeans, etc.

Table 21 shows for each of the six grades of land in the Big Richland area the average of estimated yields of corn over a period of years, the average of the estimated highest yields commonly obtained in the area, the average number of total crop failures out of 10 crops, and the number of acres involved in these averages.

Table 21. Corn. Average yield and crop failure on various grades of land, Big Richland Area. 1933.

Grade of land	Acres involved	Total crop failure in 10 years	Average yield	High yield
			Bushels	Bushels
Bottom, level				
Summer overflow	266.25	1.87	17.6	37.2
Winter overflow only	96.25	0	27.8	35.1
Never overflowed	321.0	0	23.7	31.1
Upland, level	36.0	0	21.4	30.6
Hillside, 3° to 10° slope	219.0	0	19.0	26.7
Hillside, over 10° slope	1,575.75	0	15.7	23.7

It appears that farmers who have 20 acres or more of bottom land little of which needs draining, make about as good use of

their hill land as those who have less than 20 acres of bottom land much of which needs draining.

The average amount of land per farm, by types and ultilization, for 54 farms on the lower part of Big Richland Creek, is shown in Table 22. Almost one-third of the total acreage per farm was in crops in 1933. However, 67 percent of the bottom land was in crops as compared with 19 percent of the steep upland; 27 percent of the bottom land was in pasture or idle and 28 percent of the steep upland; six percent of the bottom land was in woods and 52 percent of the steep upland.

Table 22. Average amount of land per farm by types and use, 54 farms, Big Richland Area. 1933.

Land types	Total acres per farm	Acres in crops (Incl. garden)	Acres cleared, not cropped		Acres not cleared
			Pasture	Idle	
Bottom land	16.5	11.1	2.2	2.2	1.0
Upland level	1.8	0.5	0.3	0.1	0.9
Upland rolling	4.7	1.8	0.9	0.6	1.4
Steep upland	52.9	10.2	12.2	2.9	27.6
Total	75.9	23.6	15.6	5.8	30.9

The principal crops grown on the 54 Lower Big Richland Creek farms are shown in Table 23, by type of land. More than 84 percent of the acreage in crops was corn and hay (including soybeans). Most of the corn was produced on the steep upland while practically all the hay was produced on the level bottom land. The soybean hay was produced on the bottom land subject to overflow.

Table 23. Crop acres per farm, including garden, by land types, for 54 farms, Big Richland Area. 1933.

Land types	Crop acreage							
	Corn	Meadow	Soybeans	Potatoes	Tobacco	Cane	Other	Total
Bottom land	4.1	4.0	1.7	0.2	0.1	0.3	0.7	11.1
Upland level	0.2	0.1	.0	.0	.0	.0	0.2	0.5
Upland rolling	1.1	0.1	.0	0.1	0.1	.0	0.4	1.8
Steep upland	8.5	.0	0.1	0.1	0.1	0.1	1.3	10.2
Total	13.9	4.2	1.8	0.4	0.3	0.4	2.6	23.6

Cumberland River Valley Area. This area of 3089 acres comprised all the land of 42 contiguous farms bordering the Cumberland River. The acreage owned per farm averaged 74 acres, rang-

ing from 9 to 467 acres. The number of farms smaller than 50 acres was 16, from 50 to 99 acres 17, and with 100 or more acres 9 farms. Only one farm consisted of more than 150 acres. Of the 3089 acres, 1444 acres, or 47 percent, was level land, 1018 acres being bottom land and 426 acres level upland.[1] One thousand six hundred forty-five acres, or 53 percent, of all the land in these farms was hillside land, 1334 acres or 81 percent of which was steeper than 10 degrees.

As a 10 year average the yield of corn on the bottom land was 30 bushels per acre, on the level upland 15 bushels, on the hillside land of less than 10 degrees slope 12 bushels, and on hillsides steeper than 10 degrees 20 bushels. The 42 farms averaged 73.5 acres total area, 24.25 acres bottom land, 10 acres level upland, 31.75 acres of land steeper than 10 degrees, and 7.5 acres of hillside land of less than 10 degrees slope. Because of the necessity for retarding erosion and loss of fertility, a longer rotation was used for corn on the steeper hillside land than on that which did not slope more than 10 degrees.

Table 24. Relation of bottom land per farm to the amount of land needing drainage, Cumberland River Area. 1933.

Bottom land per farm		Number of farms	Percent of bottom land needing drainage	Average width of bottom land (yards)
Range Acres	Average Acres			
0 to 9.9	2.8	7	14.3	50
10 to 19.9	14.3	9	11.9	402
20 to 29.9	22.4	13	20.5	345
30 to 39.9	34.6	7	17.3	257
40 and over	56.3	6	26.6	467
All farms	24.25	42	21.7	276
0 to 19.9	9.2	16	12.0	290
20 and over	33.5	26	22.1	268

On the 42 farms in the Cumberland River Area, 1018 acres are bottom land, of which 221 acres, or 21.7 percent, need draining (Table 24). The average farm in the area with 24.25 acres of bottom land has 5.25 acres in need of drainage. About 82 percent of the land needing drainage is cleared but only 31.3 percent was in crops in 1933. Some of the poorly drained cleared land not cropped is used to very good advantage for pasture. Some oper-

1 See footnote Page 189.

ators expressed themselves as not wanting the land drained since it affords superior grazing as it is.

In Table 24, the farms in the Cumberland River Area are grouped according to the amount of bottom land on the farm. There appears to be a tendency also in this area for farms with larger amounts of bottom land to have a larger proportion in need of drainage. Sixteen, or approximately two-fifths, of the 42 farms had less than 20 acres of bottom land. On the average a much smaller percent of the bottom land in the Cumberland River Area needed draining than in the Big Richland Area. However, the problem of draining the Cumberland River Area is much greater than in the Big Richland Area since most of this land is subject to overflow by the Cumberland River.

In Table 25, the farms in the Cumberland River Area, grouped according to the amount of bottom land on the farm and the percentages of the bottom land in need of drainage, both cleared and not cleared, are shown. A very small proportion of the land needing drainage is not cleared and much of this has been cleared and has since been allowed to grow up in willows, swamp elder and other bushes.

Table 25. Relation of the amount of bottom land per farm to the use made of land needing drainage, Cumberland River Area. 1933.

Bottom land per farm			Percent of bottom land needing drainage	
Range Acres	Average Acres	Number of farms	Cleared	Not cleared
0 to 9.9	2.8	7	14.3	0.
10 to 19.9	14.3	9	10.3	1.6
20 to 29.9	22.4	13	12.6	7.9
30 to 39.9	34.9	7	17.3	0.
40 and over	56.3	6	22.5	4.1
All farms	24.25	42	16.8	3.8
0 to 19.9	9.2	16	11.0	1.0
20 and over	33.5	26	17.8	4.2

On the 42 farms studied in the Cumberland River Area, there were 87 acres of corn on land which commonly is overflowed in summer. As in the Big Richland Area, the farmers were asked for an estimate of the number of total crop failures experienced in growing 10 crops on the land. According to these estimates, two complete failures can be expected out of 10 crops, on the average.

For the land in corn in 1933, the average annual expected loss amounts to 532 bushels, or 6.1 bushels for each acre planted. Thus the annual expected loss per acre is greater in this area than in the Big Richland Area.

A total crop failure on land which is overflowed in winter only does not occur nearly so often and consequently the average annual loss due to crop failure is much less, averaging less than one-half bushel per acre for the land in corn in 1933. The average loss was only .08 crops out of 10 crops on this land. Corn is the principal crop grown on the winter-overflow land, however, since the winter overflows prevent the production of other crops.

Table 26 shows for each of the six grades of land in the Cumberland River Area an average estimated yield of corn over a period of 10 years, the average of the highest estimated yields commonly obtained in the area, the average number of total crop failure out of 10 crops, and the number of acres involved in these averages. It will be noted that during favorable seasons the low bottom land which is subject to summer overflow produces better yields than the higher land which is overflowed in winter only, but that as an average the higher land produces over four bushels more per acre.

Table 26. Corn. Average yield and crop failure on various grades of land, Cumberland River Area. 1933.

Grade of land	Acres involved	Total crop failure in 10 years	Average yield	High yield
			Bushels	Bushels
Summer overflow	87.0	2.0	25.0	45.7
Winter overflow only	283.25	.08	29.25	37.3
Never overflowed	41.5	0	17.1	25.7
Upland level	83.25	0	15.0	21.0
Hillside, 3° to 10° slope	86.5	0	11.8	15.8
Hillside, over 10° slope	93.0	0	19.6	24.6

In neither of the two areas studied was there evidence that farmers make greater use of hill land when they have only a small amount of bottom land than when they have larger acreages of bottom land. This apparently was equally true when the characters of the bottom land is taken into consideration. This is probably due to the relatively low productivity per acre of the hillside land and the greater amount of man labor required. Possibilities for employment off the farm over a period of years

are greater in this area than on Upper Stinking Creek and therefore there is less need for clearing the hillside land even tho a smaller acreage of bottom land is available for cropping.

RELATION OF CROP LAND PER FARM AND RELIEF PER FAMILY

The income from relief during the year, August 1, 1932, to July 31, 1933, averaged $19.89 per family for 133 families on which the data were obtained in the Big Richland Area. It will be noted in Table 27 that there is a close inverse relationship between the number of acres of crops per farm and the income received by the farm family from relief sources. The average receipts from relief fall off rapidly as the acres of crops increase. Farm families having less than twenty acres of crops received an average of $30.55 per family from relief while those with twenty acres or more of crops received an average of $6.10 from relief funds.

Table 27. Relation of income from relief to total acres of land in crops, Big Richland Area, 1933.

Acres in crops	Number of farms	Acres bottom land		Number of farms and average income from relief		
		Total	Average per farm	Number	Income	Average per farm
Less than 20 acres	90	767	8.5	75	$ 2,291	$ 30.55
20 to 39.9	53	678	12.8	39	245	6.28
40 and over	22	820	37.3	19	109	5.74
All farms	165	2,265	13.7	133	$ 2,645	$ 19.89

In the Cumberland River Area the income from relief averaged $10.44 for each of the 36 families on which data were obtained (Table 28). Here again the receipts from relief sources varied inversely with the amount of land in crops. On farms

Table 28. Relation of income from relief to total acres of land in crops. Cumberland River Area. 1933.

Acres in crops	Number of farms	Acres bottom land		Number of farms and average income from relief		
		Total	Average per farm	Number	Income	Average per farm
Less than 20 acres	17	203	11.9	15	$ 376	$ 25.07
20 to 39.9	17	484	28.5	14	0	0
40 and over	8	332	41.5	7	0	0
All farms	42	1,019	24.2	36	$ 376	$ 10.44

with 20 acres or less of crops the families received an average of $25.07 from relief sources while families on farms with 20 acres or more in crops received no relief funds during the year, August 1, 1932, to July 31, 1933.

While it is recognized that the number of acres of crops grown by the families in 1933 had very little direct influence on the need for relief during the year 1932-1933, the amount of crops grown in 1933 is a very reliable indication of the amount grown in 1932 which was the source of livelihood during the period August 1, 1932, to July 31, 1933. Since the crops grown in 1933 do not in every case correspond to those grown by the family in 1932 and since the amount of relief is not always an infallible measure of the need for assistance, a perfect correlation between these two factors would not be expected. It should be noted that the acreage of bottom land increased as the acreage of crops increased in the two areas. Thus it is evident that the need for relief diminishes very greatly for farms having 20 or more acres of crops provided about three-fourths of this acreage is productive level land.

The relationship between the acreage of crops and level land to the amount of relief for the farm operators in the Lower Stinking Creek group was similar to that in the Big Richland and Cumberland River areas. The amount of relief in the lower Stinking Creek area was much greater for the farmers averaging less than 20 acres of bottom land than for those with 20 acres or more. It should be noted, however, that the farm operators on Lower Stinking Creek averaging more than 20 acres of bottom land also had receipts from sources other than the farm averaging $80 per farm, such as labor off the farm, oil and gas leases, storekeeping and teaching. Altho no information is available for the Big Richland and Cumberland River areas, in regard to outside income, it is very probable that these farmers received a portion of their income from sources other than the farm. It should not be assumed, therefore, that farmers with 20 acres of level land available for crops each year can be wholly self-supporting with income only from the farm.

The 165 farms in the Big Richland Creek Area averaged 90 acres, with 102 of these farms having less than 100 acres. The bottom land and level upland averaged 15½ acres per farm, with

an average of 46 percent of the bottom land needing drainage. Only 39 or less than one-fourth of all the farms had more than 20 acres of bottom land. Based upon the analysis of the 60 farms on Lower Stinking Creek and the relation of crop acreage and bottom land to the amount of relief in the Big Richland Area the situation in regard to the land resources on Big Richland Creek indicates that more than three-fourths of the 165 farms have insufficient land for farming of the more successful type. From the Stinking Creek study it appears that a fairly satisfactory unit of land is 20 or more acres of level land suitable for cropping. Thus it may be stated that only one-fourth of the farms on Big Richland Creek have sufficient land, if it is assumed that there is enough level land on these farms to compensate for the bottom land that it is not practicable to drain. Furthermore the drainage necessary for one-half of the bottom land on these farms, before the land can be satisfactorily cropped, is a common problem to all the owners and should be approached on a co-operative or area basis. The cost of drainage for this land would depend largely upon local wage rates since it probably can best be accomplished by the use of man labor as the principal item of cost. The profitableness of the drainage enterprise if attempted on an acreage assessment basis would depend largely upon the local demand for the products that can be produced on the drained land. It is apparent that there is at present a surplus farm population on the well-lying land on this creek, and that any program of relocation of families from the more rugged sections of the county such as the Upper Stinking Creek area would further aggravate the situation unless such families replaced a larger number who desire to relocate somewhere outside the area.

The 42 farms in the Cumberland River area averaged 74 acres per farm, with an average of 19 acres of well-drained bottom land. Thus it would appear that there are adequate land resources on the river bottom lands for the people living there at present, assuming that approximately 20 acres of level land is necessary for farming of the more successful type as indicated by the analysis of the data of the Lower Stinking Creek area. However, the river bottom lands offer opportunity for the resettlement of families from other land only to the extent that the incoming families displace the present occupants.

PROFITABLE SYSTEMS OF FARMING FOR THE AREA

What possibilities are there for farm families in the area for making a satisfactory living on their farms when they make reasonably good use of their available resources? As a partial answer to this problem, suggested systems of farming which appear to fit local conditions are presented in the form of farm budgets or detailed plans for the use of the farmers' resources. In the preparation of these budgets an effort has been made to secure the greatest possible use of the available land, capital, and labor resources. Particular consideration has been given the long-time point of view in the use of farm land. Intensive use is made of the available level land while the steep land is largely kept in pasture or trees.

In order to calculate the income which can reasonably be expected from a farm in the area, certain basic information is needed. For instance, in calculating the probable total production of crops (Table 32, Section B) when they are produced with good cultural practices, one must know what yields can be reasonably expected from the various farm crops produced within the area when good cultural practices are used. In order to calculate the seed, fertilizer, spray material and other items of cost which are needed in producing these crops (Table 32, Section C) one must know how much of the various cost items will be required for each acre of the several crops to be produced. These two types of information, for crops commonly grown in the area, are shown in Table 29.

On the other hand, if one is to calculate the probable production of livestock to be kept on the farm (Table 32, Section E) he must know the average annual production which can be anticipated if good feeding and breeding practices are followed. In order to calculate the total feeds and other materials needed to produce a given amount of livestock and livestock products (Table 32, Section D) one must know how much of these feeds and other cost items are required per unit of the various classes of livestock kept in the community. These two kinds of information for the classes of livestock commonly produced in the area are shown in Table 30.

Before one can add up the results of crop production and livestock production and bring the results together as a net return to the farm which can be easily compared with other farms one must apply prices to the crop products and the livestock products as well as to the seeds, fertilizer, feeds, other supplies and labor needed in carrying on the business. Relative prices for the common farm products and farm expense items are presented in Table 31. It should be noted that these are not intended as price predictions for any particular period but are presented primarily to emphasize the necessity for assigning values to the items to be bought and products to be sold in order to decide upon the possibility of an enterprise and in order to arrive at the probable financial returns for a given type of organization in a given farm situation. While these prices have been determined after a careful study of the prices that have prevailed in the section in recent years in so far as they are available and every effort has been made to secure comparability thruout the series, it will be necessary at any given time for farmers to make their own assumptions as to the prices that will be applicable to conditions on their own farms.

Table 29. Expected normal production requirements for crops and expected normal yields per acre.[1]

Crop	Requirements		Yield	
	Kind	Amount	Kind	Amount
Tobacco (Burley)	Seed, ozs.	.1	Tobacco leaf (all grades)	700 lbs.
	Fertilizer, 4-12-8, lbs.	350		
	Wood, bed, loads	3		
	Tobacco canvas, yds.	50		
Potatoes	Seed, bus.	13	Potatoes (1st grade)	100 bus.
	Fertilizer, 4-8-6, lbs.	400		
	Lead arsenate, lbs.	8		
Tomatoes (Canning)	Seed, ozs.	2	Ripe tomatoes	160 bus.
	Superphosphate, 20%, lbs.	300		
	Tobacco canvas, yds.	20		
Corn[2] (cut and shocked)	Seed, lbs.	7	Grain	40 bus.
	Superphosphate, 20%, lbs.	150	Stover	2,500 lbs.
	Twine, lbs.	.5		
Soybeans or cowpea hay	Seed, bus.	1.5	Hay	2 tons
	Superphosphate, 20%, lbs.	200		
Sorghum	Seed, lbs.	6	Syrup or Fodder	100 gals. or 4 tons
	Superphosphate, 20%, lbs.	150		
	Wood for evaporating, loads	1		
	Buckets, number	100		
Wheat	Seed, bus.	1.25	Grain	12 bus.
	Superphosphate, 20%, lbs.	250	Straw	1,300 lbs.
	Twine, lbs.	2	or	
	Threshing, @ 10c, dollars	1.2	Hay	1,800 lbs.
Oats, hay or grain	Seed, bus.	2.5	Hay, or	1.25 tons
	Superphosphate, 20%, lbs.	250	Grain	25.0 bus.
Rye (Nurse crop, pasture & hay)	Seed, bus.	1.5	Pasture	—
	Superphosphate, 20%, lbs.	300	Hay	1.0 tons
Mixed clover hay and pasture	Limestone, tons	2	Hay	1.5 tons
	Seed: Adapted red clover, lbs.	5		
	Alsike clover, lbs.	1		
	Korean lespedeza, lbs.	5		
	Timothy, lbs.	5		
Pasture mixture	Limestone, tons	1	Pasture	—
	Superphosphate, 20%, lbs.	400		
	Seed: Sweet clover, lbs.	5		
	Korean lespedeza, lbs.	3		
	Common lespedeza, lbs.	3		
	Orchard grass, lbs.	12		
	Ky. bluegrass, lbs.	3		
	Redtop, lbs.	2		
	White clover, lbs.	.5		

1 Production and yield data are for level land except those for pasture mixtures which are for rolling to steep upland.

2 Corn on hill land will have similar requirements other than labor but the expected yield will be about 30 bus. and 1,900 lbs. stover.

Table 30. Expected normal production requirements for livestock and assumed pro-tion per year.

	Production requirements [1]				Production	
		Combination I	Combination II	Combination III	Kind	Amount
ry cows, r head	Corn,[2] bus.	15	18	12		
	Bran,[2] lbs.	150			Whole milk, lbs.	4,500
	Cottonseed meal, lbs.	100	200	100	or	
	Legume hay, lbs.	3,000	2,500	3,800	Butterfat, lbs.	180
	Corn stover, lbs.	500	1,500		and	
	Pasture, acres	2.5	2.5	2.5	Skim-milk, lbs.	4,000
	Breeding fees, dollars	1.00	1.00	1.00	Cull cows, lbs.[3]	120
	Miscl. costs, dollars	1.00	1.00	1.00		
l calves	Whole milk, lbs.	500			Veal, lbs.	150
y calves,[3] r head th to 1 yr. age)	Corn, bus.	2	1	1		
	Bran, lbs.	100		50		
	Skim-milk, lbs.		2,000	1,500	Dairy heifer,	
	Whole milk, lbs.	450	100	100	1 yr. of age	1
	Legume hay, lbs.	600	600	800		
	Pasture, acres	.5	.5	.5		
	Miscl. costs, dollars	.10	.10	.10		
y heifers,[3] r head 2 yrs. age)	Corn, bus.	3	5			
	Bran, lbs.	100				
	Legume hay, lbs.	500	1,000	1,000	Dairy cow,	
	Corn stover, lbs.	1,000		1,000	2 yrs. of age	1
	Pasture, acres	1.5	1.5	1.5		
	Breeding fees, dollars	1.00	1.00	1.00		
	Miscl. costs, dollars	1.00	1.00	1.00		
dairy, r head	Corn, bus.		8			
	Legume hay, lbs.	1,500	2,500	2,500		
	Corn stover, lbs.	1,500	2,000			
	Pasture, acres	2.5		2.5		
	Depreciation, dollars	10.00	10.00	10.00		
	Miscl. costs, dollars	.50	.50	.50		
cows, r head ducing der ves)	Corn, bus.	5	5	8		
	Cottonseed meal, lbs.		50	50	Butterfat, lbs.	40
	Legume hay, lbs.	2,500	2,000	2,000	Skim-milk, lbs.	900
	Straw, lbs.	300		500	Cull cow,[4] lbs.	100
	Corn stover, lbs.	2,000	3,000	2,000	Feeder calf,[5] lbs.	375
	Pasture, acres	2.5	2.5	2.5		
	Breeding fees, dollars	1.00	1.00	1.00		
	Miscl. costs, dollars	.50	.50	.50		

Only one of these feed combinations is used at a given time, the particular combination depending the kind of feed grown and the prices of different feeds.

Up to 50 percent, oats may be substituted, lb. for lb., for corn or bran in any of these combinations.

In each system enough dairy heifers are included to keep up the herd. For each dairy heifer kept, t cow weighing 720 lbs. would be sold. The average weight of the cull cows sold would probably be en 750 lbs. and 850 lbs., the difference being deducted because of death losses.

If cows are culled out of the herd at 11 yrs. of age on the average, weighing 1,000 lbs. assuming a loss of 10%, there will be 100 lbs. of cull cow for sale per cow in the herd.

With a 90% calf crop raised the sale of feeder calves weighing 475 lbs., and replacing one-ninth of ows annually with heifers raised, there would be 375 lbs. of feeder calf for sale per cow.

Table 30. (Continued)

		Production requirements			Production	
		Combination I	Combination II	Combination III	Kind	Amou
Beef heifers, per head (1 to 2 yrs. of age)	Corn, bus.	4				
	Legume hay, lbs.	800	1,200			
	Corn stover, lbs.	1,000	1,000		Beef heifer, 2 yrs. of age	
	Pasture, acres	1.5	1.5			
	Breeding fees, dollars	1.00	1.00			
	Miscl. costs, dollars	.50	.50			
Bull, beef, per head	Corn, bus.			8		
	Legume hay, lbs.	1,500	1,000	800		
	Corn stover, lbs.	2,000	3,000	2,000		
	Straw, lbs.	400	400	400		
	Pasture, acres	2.5	2.5	2.5		
	Depreciation, dollars	3.00	3.00	3.00		
	Miscl. costs, dollars	.50	.50	.50		
Hogs, per 100 lbs., live wt. produced[6]	Corn, bus.	6.2	7.0	7.5		
	Tankage, lbs.	13		16		
	Shorts, lbs.	80			Pork, lbs.	1
	Skim-milk, lbs.		300			
	Pasture, acres	.1	.1	.1		
	Miscl. costs, dollars	.05	.05	.05		
	Breeding fees, dollars	.10	.10	.10		
Poultry per mature head	Corn, grain, bus.	1.5	1.25	1.2		
	Corn, ground, lbs.	10	8.0	20		
	Bran & shorts, lbs.	3.5	17.0	20	Eggs, doz.	
	Meat scrap, lbs.		2	10	Fryers, lbs.	
	Oyster shell, lbs.	4	4	4	Hens, lbs.	
	Skim-milk, lbs.	160	100			
	Miscl. costs, dollars	.02	.02	.02		
Workstock per head	Corn,[2] bus.	35	35	30		
	Mixed hay, lbs.	2,500	3,600	4,000		
	Corn stover, lbs.	2,000		1,000	Hours of work	1,0
	Pasture, acres	2.0	2.0	2.0		
	Depreciation, dollars	10.00	10.00	10.00		
	Miscl. costs, dollars	2.50	2.50	2.50		

6 Feed requirements are sufficient to take care of the breeding animals in addition to fattening pigs. If no pasture is available the grain should be increased by about 10 percent and the protein f by about 50 percent.

The systems of farming and land use suggested in the budgets are based upon assumptions derived from this study and similar studies in the Southeastern Kentucky mountains. The most significant of these assumptions are as follows:

(1) Since the upland in the area is steep and expensive to cultivate and since the level land returns much more for effort expended, it is desirable to limit the cultivated crop area to the bottom land and the level upland.[1]

1 See footnote Page 189.

Table 31. Assumed relative prices for products to be sold and expense items to be incurred.

Products to be sold		Expense items	
Item	Price	Item	Price
	Dollars		Dollars
Cash crops:		Fertilizer:	
Tobacco (Burley), per lb.	.16	Superphosphate, 20%, per 100 lbs.	1.20
Wheat, per bu.	1.10	Nitrate of soda, per 100 lbs.	2.75
Corn, per bu.	.95	Complete, 4-12-8, per 100 lbs.	1.90
Sorghum molasses, per gal.	.60	Complete, 4-8-6, per 100 lbs.	1.75
Tomatoes, per bu.	.40	Seed and Plants:	
Potatoes, per bu. (Irish)	1.00	Soybeans, Virginia, per bu.	2.60
Livestock:		Korean lespedeza, per lb.	.15
Whole milk, Grade B, per 100 lbs.	1.75	Common lespedeza, per lb.	.12
Butterfat, per lb.	.30	Red clover, adapted, per lb.	.25
Cull cows, per lb. (dairy)	.03	Alsike clover, per lb.	.25
Veal calves, per lb.	.09	Alfalfa, per lb.	.30
Cull cows, per lb. (beef)	.04	Sweet clover, per lb.	.20
Feeder calves, per lb.	.05½	White clover, per lb.	.40
Hogs, fat, per lb.	.09	Orchard grass, per lb.	.20
Feeder pigs, per lb.	.10	Redtop, per lb.	.18
Eggs, per doz.	.20	Timothy, per lb.	.07
Fryers, per lb.	.18	Ky. bluegrass, per lb.	.20
Cull hens, per lb.	.15	Rye, per bu.	1.00
Colt, yearling, each	60.00	Oats, per bu.	.75
		Corn, per bu.	2.50
		Wheat, per bu.	1.25
		Potato seed, bu.	2.00
		Tomato seed, oz.	.20
		Tobacco, burley, per oz.	1.50
Expense items		Miscellaneous:	
Item	Price	Twine, per lb.	.10
	Dollars	Canvas, per yd.	.05
Feed:		Lead arsenate, per lb.	.25
Bran, per 100 lbs.	1.75	Threshing wheat, per bu.	.10
Shorts, per 100 lbs.	1.85	Baling hay and straw, ton	2.50
C. S. meal, per 100 lbs.	2.00	Limestone, per ton	2.50
Tankage, per 100 lbs.	3.50		
Oyster shell, per 100 lbs.	1.00		
Baby chick feed, per 100 lbs.	3.00		
Oats, per bu.	.60		

(2) The level land found on each farm is small and should therefore be used to the best possible advantage. This means that wet land should be drained wherever possible, phosphate and limestone should be used to increase yields and all the level land cultivated as intensively as possible consistent with good rotation practices.

(3) The steep upland should be used for improved pasture where the slope of the land and the depth and productivity of the top soil will justify the necessary expenditure.

(4) Intensive crops like potatoes, tomatoes, beans, sorghum for syrup and tobacco, which use relatively large amounts of labor and provide a large income per acre of land, should occupy a good proportion of the bottom land if markets and other economic factors justify their production.

(5) Legumes should be grown in the rotation to help maintain the nitrogen supply, and they can be utilized most economically as hay.

(6) Dairy cows are best adapted to use the hay and pasture resources on the small farms found in the area.

(7) Poultry furnish a more profitable means of utilizing home-grown grains and skim-milk than do hogs.

(8) Since the level land will be devoted to harvested crops, some of the steep upland can be used for improved pasture in connection with the bottom land to good advantage.

(9) A greater supply of family labor than usual is available in this region and a major need is that so far as possible, the farm program should provide for full use of family labor thruout the year.

SUGGESTED SYSTEM 1

It has been shown that the average farm on Lower Big Richland Creek contains 75.9 acres of which 30.9 acres is in woods, leaving 45.0 acres available for crops. Suggested system 1 has been calculated for farms of this size with the average amount of cleared level land, 16.4 acres, and the average amount of cleared upland, 28.6. Twenty-five acres of this cleared upland is utilized as improved pasture and six-tenths of an acre is used for a garden. The balance, the least productive portion might well be devoted to woodland. Four-tenths of an acre of the level land will be in garden leaving 16 acres in rotation. The following four-year rotation is suggested for the level land:

1st year: Corn (followed with a cover crop of rye).

2nd year: Potatoes (or some other intensive crop better suited).

3rd year: Winter turf oats, hay and grain, two acres each[1] (A mixture of clovers and grass will be seeded in the oats).

4th year: Mixed clover hay (pastured after hay is cut).

A detailed budget for this system is shown in Table 32, Sections B to F. As was suggested previously the data shown in Tables 29, 30, and 31, have been used in the preparation of this budget. For example, the amount of seed, fertilizer and other materials used in the production of the four acres of potatoes is four times the requirements for an acre of potatoes given in Table 29. Similarly the total requirement for the four dairy cows is four times the feed, pasture, and other requirements given in one of the feed combinations in Table 30.

This system provides for four acres of Irish potatoes, an intensive cash crop which will yield a relatively large return per acre, or snapbeans, melons, sorghum for syrup, tomatoes and tobacco may be substituted for a part or all of the potatoes shown in this system without affecting materially the form of organization or the net income which can be expected. The conditions prevailing on the individual farm, including the adaptation of

1 Winter wheat may be substituted for oats. This would enable the family to have wheat for home use. However, feed to replace the oats would need to be purchased for livestock fed.

the soil and the special aptitudes and abilities of the farmer, will help determine which of these cash crops will prove most desirable.

If a farmer had the ability, land and other necessary equipment to produce good burley tobacco, how would this crop compare with potatoes as a cash crop in this system of farming? By using the figures in Table 29 and 31, we find that the operating costs of growing four acres of burley tobacco amount to $30.53 and the gross income is $448.00. The operating costs of

Table 32. Budget for improved use of land and other resources of an average farm in Lower Big Richland Area.

Section A. Available land resources per farm by slope, elevation and use types.

Type of land	Total acres on farm	Less acres not cleared	Acres available for crops and pasture
Bottom land	16.5	1.9	16.4
Upland, level	1.8		
Upland, rolling	4.7	1.4	3.3
Upland, steep	52.9	27.6	25.3
Totals	75.9	30.9	45.0

Section B. Crops. Acres and estimated production by land types.

Crops	Level land		Rolling and steep		Total	
	Acres	Production	Acres	Production	Acres	Production
Corn, grain	4	160 bus.	2.5	75 bus.	6.5	235 bus.
Corn, stover	(4)	10,000 lbs.	(2.5)	4,750 lbs.	(6.5)	14,750 lbs.
Potatoes	4	400 bus.	—	—	4.0	400 bus.
Oats, grain	2	50 bus.	—	—	2.0	50 bus.
Oat hay	2	5,000 lbs.	—	—	2.0	5,000 lbs.
Clover hay	4	12,000 lbs.	—	—	4.0	12,000 lbs.
Garden	.4		.6		1.0	
Pasture	(4 aftermath)		22.5		22.5	
Totals	16.4		25.6		42.0	

Section B (Cont.). Crops. Acres, production and disposition of products.

Crops	Total		Farm use		Home use		Sales	
	Acres	Production	Feed	Seed	Amount	Value	Amount	Value
Corn, grain	6.5	235 bus.	222 bus.	1 bu.	12 bus.	$11.40	—	—
Corn, stover	(6.5)	14,750 lbs.	14,750 lbs.	—	—	—	—	—
Potatoes	4.0	400 bus.	—	—	15 bus.	15.00	385 bus.	$385
Oats, grain	2.0	50 bus.	50 bus.	—	—	—	—	—
Oats, hay	2.0	5,000 lbs.	5,000 lbs.	—	—	—	—	—
Clover hay	4.0	12,000 lbs.	12,000 lbs.	—	—	—	—	—
Garden	1.0					100.00		
Pasture	22.5							
Totals	42.0					$126.40		$385

Table 32. (Continued)

Section C. Crops. Seed, fertilizer and other materials required.

Crops	Acres	Seeds			Fertilizer and other materials		
		Kind	Amount	Value	Kind	Amount	Value
Corn	6.5	Corn	½ bu.	Farm	Superphosphate, 20%	975 lbs.	$11.70
					Twine	2 lbs.	.20
Potatoes	4	Certified	52 bus.	$104.00	Lead arsenate	8 lbs.	2.00
					Fertilizer, 4-8-6	1,600 lbs.	19.20
Oats hay	4	Turf oats	10 bus.	7.50	Superphosphate, 20%	1,000 lbs.	12.00
Mixed clover hay	4	Red clover	20 lbs.	5.00			
		Alsike clover	4 lbs.	1.00	Limestone	16,000 lbs.	20.00
		Korean lesp.	10 lbs.	3.00			
		Timothy	20 lbs.	1.40			
Rye, cover crop	(6.5)	Rye	9.75 bus.	9.75			
Pasture	2.5[1]	Sweet clover	12.5 lbs.	2.50			
		Korean lesp.	7.5 lbs.	1.15			
		Common lesp.	7.5 lbs.	.90	Limestone	5,000 lbs.	6.25
		Orch. grass	30.0 lbs.	6.00	Superphosphate, 20%	1,000 lbs.	12.00
		Ky. bluegrass	7.5 lbs.	1.50			
		Redtop	5.0 lbs.	.90			
		White Clover	1.2 lbs.	.50			
Totals				$145.10			$83.35

1 The entire pasture area of 25 acres will be seeded once in ten years, requiring the seeding of 2.5 acres per year on the average.

growing four acres of potatoes total $134.00 and the gross income is $400.00. This leaves a net difference of $141.47 in favor of the tobacco. However, several times as much labor will be needed to grow and market the tobacco crop and a tobacco barn or some other provision is needed to house and cure the tobacco crop whereas no buildings are necessary for the potatoes.

If on the other hand tomatoes are substituted for the potatoes, according to data in Tables 29, and 31, the operating expenses will be $17.33 and the gross income is $256. This leaves a net balance of $27.33 in favor of the system with potatoes according to the assumed price and production data referred to. The amount of labor and equipment needed is not greatly different for the two crops.

Limestone is applied at the rate of two tons per acre for the first round of the four-year rotation on the level land, and afterwards as found necessary, perhaps one to two tons every other round of the rotation. Usually it should be applied at the time of seeding small grain in the fall, prior to seeding the mixed clovers in the spring. Two hundred fifty pounds of

Table 32. (Continued)

Section D. Livestock. Estimated feed, pasture, and other expense items required, per year.

Kind of livestock	No.	Home-grown feeds: Kind	Home-grown feeds: Amount	Pasture acres	Purchased feed and other expenses: Kind	Amount	Value
Dairy cows	4	Corn	52 bus.				
		Oats	35 bus.		Cottonseed meal	800 lbs.	$16.00
		Oat hay	2,000 lbs.	10	Breeding fees		4.00
		Clover hay	8,000 lbs.		Miscellaneous costs		4.00
		Corn stover	6,000 lbs.				
Dairy heifers	2	Oat hay	1,000 lbs.				
		Clover hay	1,000 lbs.	3	Breeding fees		$ 2.00
		Corn stover	2,000 lbs.		Miscellaneous costs		2.00
Dairy calves	2	Corn	4 bus.				
		Oat hay	600 lbs.	1	Bran	200 lbs.	$ 3.50
		Clover hay	600 lbs.		Miscellaneous costs		.20
		Whole milk	900 lbs.				
Veals	2	Whole milk	1,000 lbs.	—	—	—	—
Pigs (600 lbs., gain)	3	Corn	42 bus.		Pigs purchased (3)	150 lbs.	$15.00
		Skim-milk	1,800 lbs.	.6	Miscellaneous costs		.30
Poultry	50	Corn	84 bus.	—	Bran and shorts	175 lbs.	$ 3.15
		Skim-milk	8,000 lbs.		Oyster shell	200 lbs.	2.00
					Miscellaneous costs		1.00
Work-stock	1	Corn	32 bus.				
		Oats	14 bus.				
		Oat hay	1,000 lbs.	2	Depreciation		$10.00
		Clover hay	1,500 lbs.		Miscellaneous costs		2.50
		Corn stover	2,000 lbs.				
Totals		Corn	204 bus.				
		Oats	49 bus.		Feeds		$24.65
		Oat hay	4,600 lbs.		Livestock purchased		15.00
		Clover hay	11,100 lbs.	16.6	Breeding fees		6.00
		Whole milk	1,900 lbs.		Depreciation		10.00
		Skim-milk	9,800 lbs.		Miscellaneous costs		10.00
		Corn stover	12,000 lbs.				

superphosphate are applied at this time, and 150 additional pounds are applied to corn, in the row, at the time of planting. The small grain used in this budget is winter turf oats. The chief advantage of oats is that it furnishes more feed grain than other available small-grain crops and winter oats has the additional advantage of furnishing protection over the winter.

The budget provides for a rye cover crop to be sown on all the corn land. Four acres are sown as a cover crop and is turned under for potatoes. Two and one-half acres are sown as a cover crop and nurse crop on the steep land. It will be noted that two and one-half acres of corn are grown on the hill land where lower yields can be expected.

Table 32. (Continued)

Section E. Livestock. Estimated annual production and disposition of products.

Kind of livestock and product	Production	Disposition of products				
		Used on farm in production	Used in home		Sales	
			Amount	Value	Amount	Val
Dairy cows:						
Whole milk, 4%	18,000 lbs.	1,900 lbs.	5,000 lbs.	$87.50	444 lbs. B.F.[1]	$133.
Veal calves	300 lbs.	—	—	—	300 lbs.	27.
Cull cows	1 cow	—	—	—	1	22.
Dairy calves	2 calves	2	—	—	—	—
Dairy heifers	2 heifers	1	—	—	1	35.
Pigs:						
Pork, live wt.	750 lbs.	—	750 lbs.	67.50	—	—
Poultry:						
Eggs	400 doz.	25 doz.	100 doz.	20.00	275 doz.	55.
Fryers	100 lbs.	—	75 lbs.	13.50	25 lbs.	4.
Hens	200 lbs.	—	75 lbs.	11.25	125 lbs.	18.
Totals				$199.75		$295.

1 Butterfat produced from 11,100 lbs. of 4% milk, leaving 10,000 lbs. of skim-milk available for p and chickens.

Section F. Summary of receipts and expenses.

Income		Expenses	
Crop sales (Section B)	$ 385.00	Crops (Section C)	
Livestock and products (Section E)	295.95	Seeds	$ 145.10
		Fertilizers and other materials	83.35
Total cash receipts	$ 680.95	Livestock (Section D)	
Livestock products used in the home (Section E)	$ 199.75	Feeds purchased	24.65
Garden and other crops used in home	126.40	Livestock purchased	15.00
		Breeding fees	6.00
		Depreciation	10.00
		Miscellaneous costs	10.00
		Buildings	30.00
		Equipment	15.00
		Fences	20.00
		Taxes	18.00
		Insurance	2.00
Total gross income	$1,007.10	Total expenses	$ 379.10
		Return to labor, management and capital	$ 628.00
		Total	$1,007.10

Only a small amount of steep land can be improved for pasture each year and this can best be accomplished by breaking and cultivating the land.[1] The rye cover crop is seeded to protect the soil from erosion and to

1 In some instances steep land may be seeded to a pasture mixture without plowing by applying limestone and phosphate and seeding the bare land in the spring.

serve as a nurse crop for the grasses and clovers. Rye sown as a cover crop following corn should be sown by the middle of September, even tho it necessitates sowing before the corn is cut. Some early spring pasture may be obtained also. The limestone and superphosphate may be applied and the land smoothed down as much as possible at the time the rye is seeded.

Table 33. Budget for improved use of land and other resources of an average farm in Lower Stinking Creek Area.

Section A. Available land resources per farm by slope, elevation and use type.

Type of land	Total acres in farm	Acres not cleared	Acres available for crops and pasture
Bottom land	20	0	20
Upland, level	5	0	5
Upland, rolling	12	2	10
Upland, steep	53	53	0
Totals	90	55	35

Section B. Crops. Acres, estimated production by land types and disposition.

Crops	Level land		Rolling and steep		Total	
	Acres	Production	Acres	Production	Acres	Production
Corn, grain	6	240 bus.	2[1]	60 bus.	8	300 bus.
Corn, stover	(6)	15,000 lbs.	—	—	(6)	15,000 lbs.
Potatoes	3	300 bus.	—	—	3	300 bus.
Soybean hay	3[2]	12,000 lbs.	—	—	3	12,000 lbs.
Mixed hay	3	9,000 lbs.	—	—	3	9,000 lbs.
Pasture	9		6[1]		15	
Garden	1		—		1	
Totals	25		8		33	

Section B. (Cont.). Crops. Acres, production and disposition of products.

Crops	Total		Farm use		Home use		Sales	
	Acres	Production	Feed	Seed	Amount	Value	Amount	Value
Corn, grain	8	300 bus.	249 bus.	1 bu.	25 bus.	$25	25 bus.	$ 25
Corn, stover	(6)	15,000 lbs.	15,000 lbs.	—	—	—	—	—
Potatoes	3	300 bus.	—	—	15 bus.	15	285 bus.	285
Soybean hay	3	12,000 lbs.	12,000 lbs.	—	—	—	—	—
Mixed clover hay	3	9,000 lbs.	9,000 lbs.	—	—	—	—	—
Garden	1					100		
Pasture	15							
Totals	33					$140		$310

1 Two acres of rolling land is new seeding for pasture. Corn land will be seeded to rye in stalks in fall and then disked and seeded to pasture mixture in early spring.

2 The soybean hay will be produced on land subject to winter overflow and therefore will not be seeded to a cover crop.

Table 33. (Continued)

Section C. Crops. Seed, fertilizer and other materials required.

Crops	Acres	Seeds			Fertilizer and other materials		
		Kind	Amount	Value	Kind	Amount	Value
Corn[1]	8	Corn	1 bu.	$ 2.50	Superphosphate, 20%	1,200 lbs.	$14.40
Potatoes	3	Certified	39 bus.	78.00	Lead arsenate Complete, 4-8-6	24 lbs. 1,200 lbs.	6.00 21.00
Soybean hay	3	———	4.5 bus.	11.70	Superphosphate, 20%	600 lbs.	7.20
Rye pasture	6	———	9.0 bus.	9.00	Superphosphate, 20%	1,800 lbs.	21.60
Clover hay	3	Red clover Alsike clover Korean lesp. Timothy	15 lbs. 3 lbs. 15 lbs. 15 lbs.	3.75 .75 2.25 1.05	Limestone	12,000 lbs.	15.00
Pasture, level land	3	Sweet clover Korean lesp. Common lesp. Redtop	15 lbs. 9 lbs. 9 lbs. 6 lbs.	3.00 1.35 1.08 1.08	Superphosphate, 20% Limestone	1,200 lbs. 12,000 lbs.	14.40 15.00
Pasture,[1] rolling land	2	Sweet clover Korean lesp. Common lesp. Orchard grass Ky. bluegrass Redtop White clover	10 lbs. 6 lbs. 6 lbs. 24 lbs. 6 lbs. 4 lbs. 1 lb.	2.00 .90 .72 4.80 1.20 .72 .40	Superphosphate, 20% Limestone	800 lbs. 4,000 lbs.	9.60 5.00
Totals	28			$126.25			$129.20

1 Six acres of corn will be produced on level land and two acres on rolling land each year. The two acres of rolling land will be seeded to a pasture mixture the following spring.

The suggested mixture of grasses and clovers has sufficient variety and enough seed to give a good stand which should persist in the fields and supply abundant grazing for ten years or longer. Usually it will be necessary to keep the bushes, briars, and weeds cut the first few year until the pasture is well established after which only a small amount of cutting will be necessary.

SUGGESTED SYSTEM 2

More than eighty percent of the 176 farm operators on Stinking Creek in Knox County received income for work away from the farm. For the most part the families having the largest incomes from sources off the farm had the largest net incomes and the higher standards of living. A dependable source of income from work away from the farm appears to be a requisite for a satisfactory living on much of the land in the area. Therefore, in

Table 33. (Continued)

Section D. Livestock. Number and estimated feed, pasture, and other expense items required per year.

Kind of livestock	No.	Home-grown feeds: Kind	Home-grown feeds: Amount	Pasture acres	Purchased feed and other expenses: Kind	Amount	Value
Dairy cows	4	Corn	60 bus.	10.0	Bran	600 lbs.	$10.50
		Legume hay	12,000 lbs.		Cottonseed meal	400 lbs.	8.00
		Corn stover	2,000 lbs.		Breeding fees		4.00
					Miscellaneous costs		4.00
Veals	3	Whole milk	1,500 lbs.	—	—	—	—
Dairy calves	1	Corn	2 bus.	.5	Bran	100 lbs.	1.75
		Whole milk	450 lbs.				
		Legume hay	600 lbs.				
Dairy heifers	1	Legume hay	1,000 lbs.	1.5	Breeding fees		1.00
		Corn stover	1,000 lbs.		Miscellaneous costs		1.00
Pigs	3	Corn	42 bus.	—	Pigs purchased (3)	150 lbs.	15.00
		Skim-milk	1,800 lbs.		Miscellaneous costs		1.00
Poultry	50	Corn, grain	75 bus.	—	Bran and shorts	175 lbs.	3.15
		Corn, ground	9 bus.		Oyster shell	200 lbs.	2.00
		Skim-milk	8,000 lbs.		Miscellaneous costs		1.00
Work stock	2	Corn	70 bus.	4.0	Depreciation		20.00
		Legume hay	5,000 lbs.		Miscellaneous costs		5.00
		Corn stover	4,000 lbs.				
Totals		Corn	258 bus.	16.0	Feeds		25.40
		Legume hay	18,600 lbs.		Pigs purchased		15.00
		Corn stover	7,000 lbs.		Breeding fees		5.00
		Skim-milk	9,800 lbs.		Depreciation		20.00
		Whole milk	1,950 lbs.		Miscellaneous costs		12.00

setting up this budget for farming in the area, it has been assumed that some seasonal work away from the farm would be available. The proposed budget applies only to farms established on fairly level land with a satisfactory all-year automobile road, preferably near a local market and easily accessible to seasonal work off the farm.

The average farm on Lower Stinking Creek has slightly more than 20 acres of level land. Most of this is bottom land and part of it is subject to overflow in winter. Most farms in this area contain only a small proportion of rolling upland and large proportion of steep upland. Assuming these average conditions a budget for a 90-acre farm having 20 acres bottom land, 5 acres level upland, 12 acres rolling upland, and 53 acres steep upland has been calculated. The 25 acres of level land and ten of the 12 acres of rolling upland are utilized for crops and pasture. The remaining

Table 33. (Continued)

Section E. Livestock. Estimated annual production and disposition of products.

Kind of livestock and product	Production	Disposition of products				
		Used on farm in production	Used in home		Sales	
			Amount	Value	Amount	Val
Dairy cows:						
Milk, 4%	18,000 lbs.	1,950 lbs.	5,000 lbs.	$87.50	442 lbs. B.F.[1]	$132.
Veal (3)	450 lbs.	—	—	—	450 lbs.	40.
Cull cow	1 cow	—	—	—	1 cow	22.
Dairy calf	1 calf	1 calf	—	—	—	—
Dairy heifer	1 heifer	1 heifer	—	—	—	—
Pigs:						
Pork, live wt.	750 lbs.	—	750 lbs.	67.50	—	—
Poultry:						
Eggs	400 doz.	25 doz.	100 doz.	20.00	275 doz.	55.
Fryers	100 lbs.	—	75 lbs.	13.50	25 lbs.	4.
Hens	200 lbs.	—	75 lbs.	11.25	125 lbs.	18.
Totals				$199.75		$273.

1 Butterfat produced from 11,100 lbs. of 4% milk, leaving 10,000 lbs. of skim-milk available for p and chickens.

Section F. Summary of receipts and expenses.[1]

Income		Expenses	
Crop sales (Section B)	$ 310.00	Crops (Section C)	
Livestock and livestock products (Section E)	273.85	Seeds	$ 126.25
Work off the farm (3 months)	150.00	Fertilizers and other materials	129.20
		Livestock (Section D)	
Total cash receipts[1]	$ 733.85	Feeds purchased	25.40
Livestock products used in the home (Section E)	$ 199.75	Pigs purchased	15.00
Garden and other products used in home (Section B)	140.00	Breeding fees	5.00
		Depreciation	20.00
Total gross income	$1,073.60	Miscellaneous expense	12.00
		Buildings	30.00
		Equipment	15.00
		Fences	20.00
		Taxes and insurance	20.00
		Total expenses	$ 417.85
		Return to labor, management and capital	$ 655.75
		Total	$1,073.60

1 Variations from the proposed farm organization would be necessary to fit individual situations, particularly with regard to work off the farm. Therefore, the data presented should be considered as suggestive for making adjustments on individual farms.

55 acres are utilized for forest trees. The following four-year rotation is suggested for the level land:

1st year: Corn (followed with a cover crop of rye on the land not subject to winter overflow).

2nd year: Potatoes (on non-overflow land).
Soybeans (on land subject to overflow).

3rd year: Rye pasture (seeded in spring to hay and pasture grasses).

4th year: Mixed clover hay (on non-overflow land). Pastured after hay is cut.
Pasture (on overflow land).

A detailed plan for this system is shown in Table 33, Sections B to F. The data shown in Tables 29, 30, and 31, have been used in the preparation of this budget. Limestone and fertilizer requirement on the level land are similar to those described for System 1. One acre of the 25 acres of level land is used for home garden and truck.

The following five-year rotation is suggested for the 10 acres of rolling land utilized for crops and pasture (arranged in a five-year rotation):

1st year: Corn (rye seeded in stalks in fall).

2nd year: New seeding (corn stalks disked in spring, lime and fertilizer for pasture seeding applied and pasture mixture seeded).

3rd to 5th year: Pasture.

The length of the rotation suggested for the rolling land is based upon the probable need for reseeding the land after a few years by cultivating one year to remove weeds and bushes, followed with a cover crop in the fall and spring seeding as outlined above. This land usually is in a very low state of productivity and therefore will require considerable care in building up. After two or three rounds of this five-year rotation it could probably be lengthened to ten years or more.

Where desirable and practicable, snapbeans, melons, sorghum for syrup, tomatoes or tobacco can be substituted for all or part of the potatoes in this System, as discussed in Suggested System 1, without materially affecting the rotation.

SUMMARY

Knox County is typical of the Mountain Region of Eastern and Southern Kentucky comprising 38 counties or parts of counties. The lack of an adequate acreage of arable land in this region in relation to the number of persons living on the land, coupled with the lack of opportunities for nonfarming employment, has resulted in a large amount of poverty.

The territory in the study included all the land in two contiguous magisterial districts comprising 68,000 acres making up the entire drainage basin of Stinking Creek, one of the important tributaries of Cumberland River. This is a typical situation in which a

relatively dense population is undertaking to eke out a living by the cultivation of steep and eroded land.

The index of natural increase for the rural farm population of Knox County in 1930 was 193 as compared with 148 for the entire United States. The population per square mile in this area is greater than that of many of the more level and fertile agricultural counties of Kentucky.

The value of land and buildings averaged $1,167 per farm, or about $18 per acre, for the 176 farms. The dwelling houses averaged $187 in value. The farms averaged 63½ acres in total area. Corn was the principal crop and averaged 9.7 acres per farm. More than a third of the operators had no well-lying land and only about half of them had as much as five acres of well-lying land.

The number of persons per family averaged 5½ and the income available for spending averaged $68 per family. The spendable income available for the 60 families living in the rugged upper Stinking Creek territory was $48 per family as compared with $106 for the families living in the more favorable lower Stinking Creek territory.

Corn constituted approximately 68 percent of the acreage of all the land in harvested crops. Two-thirds of the corn is grown on hillsides having slopes ranging from 10 to 40 degrees or more. The result is that the hillsides have reached a stage of advanced erosion and very low productivity. The corn on the bottom land yielded almost three times as many bushels per day of man labor as that on the hill land.

On much of this steep land, young trees which, in a few years, would be large enough for saw timber, are constantly being destroyed to make way for corn patches. A few crops of corn exhaust the humus supply and cause such erosion that the land becomes incapable of growing either corn or good timber. The recleared land in many cases is capable of yielding not more than 10 bushels of corn per acre in a normal season. The entire crop of one man is often limited to three to five acres, or a total production of 40 to 60 bushels.

A study of a typical cropping cycle of 24 years on 28 hillside fields indicated that during the cycle an average of five crops of corn may be expected on such land cleared for the first time and

three crops after the land is cleared a second time. At the end of this cycle the economic usefulness of the land has been practically destroyed.

The principal bases used in classifying the land in this study were present use, topography, soil, and the condition of buildings. The land was divided into three classes according to the intensity of present and probable future uses. Land Class I, practically uninhabited and consisting of land almost wholly rough forest and waste land adapted primarily to the growing of trees, made up seven percent of the total acreage; land Class II consisting of land now largely in farms but unsuited to agricultural use, about 76 percent of the total acreage; and land Class III, fairly good agricultural land, about one-sixth of the total acreage. Rough forest and idle land made up 98 percent of Class I land, 71 percent of Class II land and 31 percent of Class III land.

Sixty-seven percent of the houses on Class II land and fifty percent on Class III land were classified as poor or dilapidated. Houses classified as poor usually had only one or two rooms and were of box or log construction, with four windows or less. Twenty-three and one-half percent of the farm dwelling houses situated on Class II land and 45.7 percent on Class III land were classified as good or fair.

Twenty-eight percent of the families averaged one person or less per room, 35.6 percent had from 1.1 to 2 persons per room, 25 percent from 2.1 to 3 persons per room and 11.6 percent 3.1 or more persons per room.

To throw light on the capability of the more level land for furnishing a living for its operators and affording resettlement opportunities for families living on rough submarginal land, a land-use analysis was made of two blocks of land in the same county located along the Cumberland River and in the valley of Big Richland Creek, a tributary of Cumberland River.

The block of land along Big Richland Creek consisted of about 15,000 acres made up of all the land of 165 contiguous farms, these averaging 90 acres in size, 17½ percent being level land, and the remainder steep hillside land. Forty-six percent of the level land was in need of drainage. On the 2,272 acres of bottom land there were 266 acres of corn land which usually is overflowed in summer. The

total crop failures resulting from such overflows amounted to 1.8 crops out of 10 crops, the average annual loss being 4.3 bushels for each acre of corn planted.

The Cumberland River block consisted of 3,089 acres comprising all the land of 42 contiguous farms bordering the river, the farms averaging 74 acres in size, 47 percent being level and 53 percent hillside land. Of the 1,018 acres of bottom land 21.7 percent was in need of drainage. On this bottom land there were 87 acres of corn on land which commonly is overflowed in summer. On this land there are two complete crop failures out of 10 crops of corn, the average annual loss being 6.1 bushels for each acre of corn planted.

The study indicates that more than three-fourths of the 165 farms in the Big Richland Creek bottoms have insufficient land for successful full-time farming; that there is at present a surplus farm population on this creek; and that any program of relocation of families from more rugged sections would further aggravate the situation.

The block of land made up of the 42 farms in the Cumberland River area furnishes land resources sufficient for the people living on this land at present and offers no opportunity for the resettlement of families from other land except to the extent that incoming families replace present occupants.

Plans for two effective farming systems are presented on pages 204 to 213. These systems require a minimum of between 18 and 25 acres of well-lying land per farm and are based on the use of intensive enterprises and methods. Because well-lying land is so scarce in the area, there is the possibility for only a few families to have such farms as those suggested and these farms would be confined to land along the river and lower ends of the creeks.

PROPOSALS FOR THE BETTERMENT OF CONDITIONS FOR THE PEOPLE OF THE AREA

The problem of dealing with submarginal land in this area differs from that in submarginal areas from which most of the people have migrated. As has already been pointed out, this eastern Kentucky area has a relatively dense population. "It is characteristic of our Kentucky mountain areas that for the time being, many of the occupants are satisfied to remain, partly because they are unac-

quainted with or unadapted to other modes of existence. Any proposal regarding such land must take these people into consideration. Although the land is essentially submarginal from the point of view of commercial farming, any attempt at the present time to stimulate the evacuation of these areas would be unwise. On the contrary, a wiser present policy is to help them make the best of their meager environment."[1]

An analysis of the available facts seems to warrant the conclusion that areas of land, such as that designated as Class I, might well be reserved at once as permanent forest land. On land in Class II, consisting of the rough land in the upper reaches of the forks of the creeks, farming should eventually be abandoned and the land reserved for permanent forest use. Land in Class III, consisting of areas with a considerable proportion of productive, level arable land, may well be used permanently for agricultural production.

The immediate need is to find means of making the maximum use of existing land resources. This would call for the use of the more intensive kinds of crops and intensifying the culture of all crops on the limited areas of good agricultural land.

Families on the rougher, poorer land should be encouraged and assisted to develop as completely as possible their limited land resources with the object in view of living where they are until opportunities for resettlement in industry or on suitable agricultural land become available. Some of the sloping land might well be terraced. On farms where there is no level land the special preparation of garden plats of limited area by the construction of retaining walls on productive land would enable families to produce a considerable part of their food supplies and thereby lessen the calls for public relief. Eventually such farms should be evacuated, but the best policy requires that the evacuation be done slowly and voluntarily. A period of a generation or more might be required for this evacuation.

The number of persons who have migrated from the area in past years has been relatively small, this being partly due to the isolated situation of the area caused by physiographic barriers and lack of roads and railroads to the outside world. The people remained in their meager environment because they were unacquainted with

1 From an address by Dean Thomas Cooper of the College of Agriculture, University of Kentucky.

and fearful of other places of abode outside their own region. However, a large proportion of the limited number who did migrate to other sections made valuable contributions to the life of the communities to which they went and for most of them the change of location meant a notable improvement of their economic and social well being.

Families that can get industrial employment outside the region should be encouraged to do so and industrial enterprises might well be encouraged to locate at various points in the area. However, the outlook for getting such industries started is one of the most difficult and discouraging aspects of the rehabilitation of these people. A limited number of the families of the area possess the qualifications necessary for successful farming in areas of good agricultural land. Such families, if they desire to relocate, should be given guidance and assistance. The relocation should be as near the home locality as feasible. To test the possibilities of such relocation it may be advisable for a government agency to furnish aid by acquiring tracts of land to be made available to competent families on a long-time plan of repayment and low interest rates.

Since only a minor fraction of these stranded families possess the qualifications for commercialized farming, and since a large proportion of them require the close supervision common in urban jobs, the resettlement of such families, if undertaken, should be on small subsistence plats near possible opportunities for urban occupation. This plan is the easiest to execute, involves the smallest outlay per family and offers the best prospect for success.

The proposal to rehabilitate families in their present location is predicated on the fact that, at present, industry or other nonfarming work is not available elsewhere for anything like the number of families which need to be rehabilitated. Expenditures on permanent structures for the rehabilitation of such families on the submarginal land upon which they are now living should be confined for the most part to minor repairs to make the present houses habitable. The young people would be expected to leave these submarginal farms and the land would ultimately be evacuated with the demise of the older people. The governmental agency in buying the land might well, in the case of the older owners, pay for it by the issuance of life annuity certificates, meanwhile permitting

the occupants to use the dwelling houses and the land under rigidly prescribed conditions. Cultivation would be permitted only on the level land, or the gentler slopes. The occupants would have the use of the present house and such land for intertilled crops and such pasture land, and firewood as might thus be permitted. At the death of the operators, entire possession would be taken by the governmental agency and the land would go back into forest.

The reforestation of such land would be a distinct public benefit. It would retard the run-off of water and alleviate the flooding of towns and cities on the lower reaches of the streams. It would lessen the washing off of soil into smaller and larger stream channels, filling them with silt. It would correct a maladjustment of population and serve as a means for rural slum clearance, changing the condition of the people from one of destitution and hopelessness to one of better economic and social opportunities.[1]

1 The following quotation from an address of Secretary of Agriculture H. A. Wallace, made in Louisville,October 2, 1937, is significant in connection with the problem of dwellers on poor-land farms in the Kentucky mountains: "In those areas, as for example in the mountains where farms are very small and the soil is poor, there is absolutely no way of putting into the hands of the average farmer as much income as in those regions where the farms are large and the soil is rich. In working out our national farm programs, therefore, it is essential that as we try to discover what is fair between the regions we keep in mind the past situation. But in so doing we are exceedingly anxious to make it possible for those areas where the per capita earnings have been low to earn more. At the same time we do not want to encourage inefficient farming, or the continuance of farming on such small farms or such poor farms that the children have no chance."

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TOBACCO MOSAIC
SOURCES OF INFECTION AND CONTROL

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Tobacco Mosaic
Sources of Infection and Control

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Tobacco mosaic control depends upon determining the sources of initial infection in the plant bed and field and eliminating them, and eliminating, or avoiding touching infected plants in the field, to avoid spread. Until comparatively recently the causes of the occurrence of mosaic in plant beds and fields were not known but now that much evidence on the source of infection has been accumulated, it seems desirable to evaluate it and try to arrive at some conclusion as to the most common sources so that the best methods of control may be developed. As long as there is disagreement as to the chief sources of plant-bed and field infection, it will be virtually impossible to test uniformly the value of recommended practices (18, 20, 23) in all the tobacco-growing areas of the country. It is proposed in this Bulletin to analyze the material which has been published on sources of mosaic infection and add experimental and observational evidence on sources of infection and on control.

FOUR SOURCES OF INFECTION

Because it retains infectivity after drying, tobacco mosaic virus is in a class alone among the viruses which affect annual plants, as far as sources of infection and control measures are concerned. Four possible sources of tobacco mosaic virus must be given consideration in control of mosaic: 1, the contaminated hands of workers, and tools and equipment used in caring for the crop; 2, the living infected plant and dying or dead plant parts; 3, insects temporarily made viruliferous, and 4, contaminated soil.

PERSONALLY USED TOBACCO A SOURCE OF MOSAIC

Mayer (17) in 1886 probably presented the first evidence, inadvertently, that man himself is chiefly responsible for infection in

the field. He stated in a footnote that "Many held the opinion that the manner of setting is of great importance. This went so far that, in Amerongen, any worker who was reputed not to be good at transplanting and therefore had much mosaic tobacco to answer for, was nicknamed Mosaic Johnny (Jan Bont). However, opinions as to what constituted faulty transplanting were diverse ('bunt')."[1]

Workmen Introduce Infection. In 1922 the senior writer began to keep records of distribution of tobacco mosaic in the plantings on the Kentucky Experiment Station farm. No information was available on the source of plant-bed infection other than that of Clinton (7) who showed that where tobacco decoctions and other tobacco material had been added to the bed, mosaic followed. On the Kentucky Station farm infected *Solanum carolinense* and *Physalis sp.* were common. Consequently a permanent plant-bed site was established and the weed hosts were eliminated from it. In 1924 the beds appeared to be free from mosaic at first pulling but in certain rows in the field set with plants from them about 30 percent showed mosaic when growth began. Other groups of rows were nearly or quite free from infection. In 1925, after a similar experience, it was concluded that elimination of *Solanum carolinense* and *Physalis* from tightly boxed and covered beds which were not weeded had no effect whatever in reducing mosaic in the field. Tests showed that in all probability infection arose from chewing tobacco used by workmen (4).

Barn-cured Tobacco. The 1924 planting (20) was on a plot which had had tobacco heavily infected with mosaic the previous year, but the distribution of mosaic in the field clearly indicated that infection occurred during pulling or setting and could not have come from the soil. In 1925 the plot used had not grown a crop of tobacco for 4 years. The plant bed was free from mosaic at pulling time. Both men who pulled plants were in the habit of chewing barn-cured tobacco but one used no tobacco until near the end of pulling when he chewed 5-year-old dark-fired tobacco subsequently found to be contaminated, while the other puller chewed manufactured plug while pulling. Neither man washed his hands before commencing pulling and consequently their hands must

1 Translation by the authors.

have been contaminated with virus. Mosaic occurred thruout the field in about the proportion shown in rows 115 to 124, (table 1). Higher infection in the last 8 rows was evidently caused by the puller who began chewing barn-cured tobacco toward the end of pulling. The lower infection in the remainder of the field might have originated from the commercial plug, but more probably came from the hands of the workers which were already contaminated from barn-cured tobacco before pulling commenced. It could not have arisen from the soil or from the plant bed. The distribution given in table 1 is typical of that caused by workmen who chew or smoke contaminated tobacco while pulling plants.

Table 1. Distribution of mosaic typical of that originating from contaminated hands of workers at pulling time. Record made about 30 days after setting, 1925.

Row number	Mosaic plants	Healthy plants
115	3	92
116	0	98
117	1	96
118	1	102
119	1	94
120	0	99
121	7	93
122	0	96
123	0	97
124	1	101
125	5	90
126	4	98
127	16	75
128	17	85
129	8	89
130	17	83
131	5	95
132	7	83

In 1926 the farm hands were given sterile manufactured and sterile barn-cured tobacco to chew while pulling and setting. Forty-four hundredths of one percent mosaic developed about three weeks after setting, in plantings including about 60,000 plants. This was only 1/18 the amount of infection which occurred following setting in the three years, 1922-1924, when no precautions were taken to control mosaic. In 1927, with the same precautions, 35 mosaic plants were found in a total of about 70,000 plants set on the farm. It appeared certain from these results and experiments in which the hands were dipped in inoculum made of dried mosaic

tobacco and water, and tests in which pullers chewed contaminated tobacco while pulling and others pulled with clean hands, that a plant bed might be entirely free from mosaic at pulling time, but a heavily-infected crop might be set from it in land which had not grown tobacco for years, if the men who pulled plants chewed contaminated tobacco while pulling (table 2); and that contaminated hands of weeders offered the correct explanation for plant-bed infection where mosaic was found in the bed before pulling time. The results of these studies were published in 1927 in Kentucky Agricultural Experiment Station Bulletin 280 (20).

Table 2. Mosaic infection from the hands of workers. Plants pulled while hands of puller were contaminated by handling or chewing barn-cured tobacco compared with plants pulled with clean hands. In each set of tests plants were pulled from the same plant bed.

	Treatment	Mosaic Plants	Healthy Plants	Percent Mosaic
Lexington				
1926	Hands dipped in decoction of barn-cured tobacco	99	41	70.7
	Clean hands	0	138	0.0
1927	Chewed barn-cured tobacco and occasionally spit on hands	62	78	44.3
	Clean hands	0	80	0.0
1927	Chewed barn-cured tobacco, wiped mouth occasionally	39	839	4.4
	Clean hands	1	836	0.1
	Chewed barn-cured tobacco	19	341	5.3
1928	Contaminated soil. Puller chewed 2-year-old barn-cured tobacco. Plants in even numbered rows 2-34	33	889	3.6
	Odd rows 1-35, clean hands	0	1,015	0.0
1928	Puller who chewed barn-cured tobacco, washed hands in water only and then used sterile plug	32	553	5.5
	Same puller, virus largely worn off hands	17	54,325	0.03
Princeton				
1926	Chewed barn-cured tobacco, wiped mouth occasionally	219[1]	429	33.8
	Clean hands	58[1]	590	9.0
	Clean hands, different field	0	8,500	0.0
1927	Chewed barn-cured tobacco from mosaic-free crop of 1926	4	708	0.5
	Clean hands	1	711	0.1

1 Record made 48 days after setting; cultivation had been across plots.

Experimental Contamination of Workers' Hands. Experiments conducted between 1926 and 1928 (table 2) prove that tobacco plants may be infected with mosaic at pulling time if the

hands of the workers are dipped in a water decoction of barn-cured tobacco; if the worker chews barn-cured tobacco and occasionally spits on his hands or wipes his mouth occasionally; or if the puller chewed barn-cured tobacco and made no effort to contaminate his fingers, other than handling the dry tobacco.

Further proof of the part which handling dry, viruliferous tobacco and then pulling plants may play in field infection, was furnished by an experiment performed in 1937. Twists were made from tobacco infected the previous year with yellow mosaic, mosaic burn, and a non-burn green mosaic, respectively. Three pullers each crushed a piece of one of the twists in his hands, which had just been thoroly washed, dusted them off until they appeared free from bits of tobacco, and then pulled four lots of about 75 plants each which were numbered 1 to 4 and set in the field in that order with a machine setter. After growth commenced, a record was kept of the number of infected plants and the kind of mosaic, which appeared in each row. At each observation infected plants were removed. The results are given in table 3. Of the 878 plants which survived transplanting, two hundred and sixty-nine, or 30.6 percent, developed mosaic. In all instances but one the mosaic which developed was of the same kind as that contained in the twist handled by the man who pulled the plants. If each puller had continued to pull sufficient plants for one acre and no further infection had occurred, which is unlikely, over 1.2 percent of the plants set in the 3 acres would have developed mosaic soon after setting, as a result of each puller contaminating his hands once. Fifteen days after setting, 22 mosaic plants were found in the small portion of the bed from which the plants were pulled but none were found in the remainder of the bed. In this experiment where there appeared to be little if any field spread, mosaic plants were found 38 days after setting. These were small plants which started growth slowly and appeared to have been infected at pulling time. This is a longer incubation period than is usual with tobacco mosaic but in small, slow-growing field plants symptoms are difficult to see until growth commences. The drop off in infection as the virus wore off the fingers is also worthy of note.

It is generally assumed that washing the hands with soap and water is sufficient to remove virus from the hands if they are con-

taminated. This conclusion is usually based on inoculation of a few plants following washing. The writers are gradually coming to the conclusion that it is an extremely difficult matter to completely remove virus from the rough hands of workmen who handle viruliferous tobacco constantly. It seems entirely probable that low percentages of infection in fields where all known precautions have been taken may be caused by the gradual wearing off of virus embedded in the rough skin of the hands of the pullers or setters.

The objection has been raised (14) that "it is, of course, quite impossible to judge from such trials (intentional contamination of hands) as to how much infection of this type actually results under field conditions." This is hardly a valid criticism for it has proved to be a simple matter to raise beds of plants entirely free from

Table 3. Infection from hands of pullers on which contaminated dry tobacco was rubbed. Each of 3 men crushed a piece of contaminated twist tobacco in his dry hands, brushed them off, and then pulled four lots of tobacco which were set in the order pulled, on June 2, 1937, with a machine setter.

Row no.	Order of pulling	Number of infected plants found and removed on 6/18	6/21	6/25	6/28	7/7	7/10	Mosaic plants	Total plants	Percent mosaic	Kind of Mosaic: On the hands	Kind of Mosaic: In the field
121	1st	35	5	1	3	2	0	46	76	60.5	Yellow	Yellow
122	2nd	23	4	3	3	1	0	34	76	44.7	Yellow	Yellow
123	3rd	6	1	0	2	3	0	12	74	16.2	Yellow	Yellow
124	4th	2	1	0	1	0	1[1]	5	75	6.7	Yellow	Yellow
125	1st	40	6	0	0	0	1	47	73	64.4	Burn	Burn
126	2nd	13	3	2	2	2	1	23	74	31.1	Burn	Burn
127	3rd	5	1	0	0	0	0	6	71	8.4	Burn	Burn
128	4th	2	0	1	1	0	0	4	74	5.4	Burn	Burn
129	1st	34	3	2	8	2	0	49	71	69.0	Green	Green
130	2nd	11	3	0	4	2	2	22	70	31.4	Green	Green
131	3rd	5	4	1	6	0	1	17	73	23.3	Green	Green
132	4th	4	0	0	0	0	1	5	71	7.0	Green	Green
133		0	0	0	0	0		0	72	0.0	None	None
134		0	0	0	0	0		0	74	0.0	None	None

1 Mosaic burn.

mosaic year after year. Soil contamination can be eliminated by planting in a field which has not grown tobacco for years. Plants pulled and set with clean hands remain mosaic free for weeks, but plants pulled by men whose hands are contaminated with virus from handling barn-cured tobacco regularly have some mosaic. In the type of experiment reported in table 3 where three different strains of mosaic were used, each easily recognizable, mosaic infection could easily be traced to its true source. Each year many

farmers in Kentucky carry on, unconsciously, well-conducted tests which almost certainly prove that infection arises from the hands of the worker contaminated from handling barn-cured tobacco since all other known sources of infection are eliminated by their routine practices (table 4).

Table 4. Extent of infection of tobacco plants pulled and set by men some of whom used manufactured tobacco while pulling and setting, and some who used barn-cured tobacco. All plants were pulled from the same plant bed and all the plots or fields were set from first pulling, on a farm in Todd County. 1937.

Field	Number of plants			Percent of mosaic plants	Tobacco chewed by pullers and setters
	With mosaic	With mosaic burn	Healthy		
1	1	0	540	0.2	Manufactured tobacco
2	0	0	640	0.0	Manufactured tobacco
3	0	0	600	0.0	Manufactured tobacco
4a, Rows 1-50	15	3	10,689	0.2	Manufactured tobacco[2]
4b, Rows 51-89	354	350	7,803	8.3	Barn cured
5	20	0	300	6.3	Barn cured
6	187[1]		1,151	14.0	Barn cured

1 Mosaic and mosaic burn. Large field but only 1,338 plants counted.
2 Field 4 not cultivated for 11 years previously. Fields 1-2-3-5 in tobacco 3 or 4 years previously.

In 1936, thru accident, a well-conducted experiment was performed on the Experiment Station farm which illustrates the part which handling viruliferous tobacco may play in field infection. Two men pulled plants for a planting comprising, in all, 13,500 plants. When they were informed that they had pulled all the plants necessary to complete the planting, which was the last for the season, they went to the barn where one of them had placed a twist of barn-cured tobacco. He took a bite of it and after a time was told that there were not enough plants. Without washing, they went back to the plant bed and pulled a small lot of plants which were taken immediately to the field and set. They continued pulling until a sufficient number had been pulled to complete the planting. At the first mosaic count 20 days later, 18 mosaic plants were found in 8 rows. The remainder of the field was free from mosaic. With one exception the affected plants were either all even numbered or all odd numbered, where two or more

mosaic plants were found in a row, indicating that one man on the setter set the infected plants pulled by the man who chewed, while the other set uninfected ones.

Inquiry as to the source of these infections brought out the story just told. The mosaic plants were all affected with a severe burning type of mosaic. Further inquiry proved that the men had saved their chewing tobacco from a plot inoculated the previous summer with a burning strain of the virus. There appeared to be

Table 5. Mosaic in plantings on the Experiment Station farm over a 16-year period. The counts during the first three years are typical of those in previous years before control measures were initiated. From 1926 to 1937 the men were furnished with chewing tobacco believed to be mosaic free.

Year	Tobacco chewed by workers	Plants set	Mosaic plants at 3 to 4 weeks	
			Number	Percent
1922	Barn cured	14,000	1,260	9.00
1923	Barn cured	14,000	840	6.00
1924	Barn cured	14,000	1,218	8.70
1925	Commercial plug and natural leaf 5 years old	14,000	294	2.10
1926	Sterilized twist and plug	14,000	62	0.44
1927	Sterilized twist and plug	70,000	35	0.05
1928	Sterilized twist and plug	39,780	8	0.02
1929	Sterilized twist and plug	30,000	3	0.01
1930	Sterilized twist and plug	57,355	94	0.16
1931	Unsterilized Star plug	66,600	5	0.01
1932	Unsterilized Star plug	65,369	47	0.07
1933	Unsterilized Star plug	52,383	665[1]	1.27
1934	Sterilized and unsterilized Star plug	50,846	64	0.13
1935	Unsterilized Star plug	56,873	61	0.10
1936	Unsterilized Star plug	13,500	18[2]	0.13
1936	Unsterilized Star plug	12,800	38	0.30
1937	Dry air sterilized barn-cured tobacco	14,624	2	0.01
1937	Dry air sterilized barn-cured tobacco	15,542	21	0.14

1 Count made 40 days after setting and after cultivation and hoeing. Beds were very weedy. Men weeded who were in the habit of chewing barn-cured tobacco but did not use it while weeding. At first cultivation, many plants were covered with soil. These were uncovered by the men while hoeing. In one planting of over 13,000 plants ¼ of the mosaic plants were in 4 rows.

2 The mosaic plants were all mosaic burn and were traced to one man who handled and chewed tobacco from a mosaic-burn plot of the previous year.

no doubt that the 18 plants had become infected as the result of this man handling viruliferous tobacco for this short period.

Control of Tobacco Mosaic. Since 1926 mosaic has been controlled fairly effectively on the Station farm using the simple

precautions of burning or steaming the beds thoroly to reduce weeding, having men weed who do not use tobacco, and having the pullers and setters wash their hands and use mosaic-free tobacco (table 5).

During the past ten years instructions on mosaic control based on prevention of infection from the contaminated hands of workers who chew or smoke tobacco, have been given to individual farmers and to tobacco growers in general thru the press and extension service in Kentucky (23), and more recently to the press generally by the United States Department of Agriculture (19). Intelligent farmers recognize very quickly the importance of chewing and smoking tobacco as sources of infection and many have now put mosaic control into successful practice on their farms.

Examples of successful mosaic control over a ten-year or longer period on four farms in widely separated parts of Kentucky are given in table 6. At Greenville and Campbellsville soil experiment fields mosaic control has been nearly perfect. At Mayfield control has been successful where precautions were followed but in years when no precautions were taken there was a great deal of mosaic. The man who cared for this field from 1927 to 1933 was never convinced of the necessity of taking precautions against mosaic and only took them when he was furnished with sterile tobacco and then was not careful to wash his hands before beginning operations in the bed and field. Since employing another man who does not use tobacco and realizes the necessity of precautions against mosaic infection, mosaic has ceased to be a problem on this field. At Princeton a crew of men most of whom chew barn-cured tobacco, pulled and set plants. They use none during these operations and wash their hands in soap and water before commencing operations. Mosaic has been successfully controlled at Princeton altho not eliminated completely, perhaps because no precautions were taken during the summer to prevent infection from the worker's hands.

A certain religious sect in Kentucky prohibits its members from using tobacco in any form. Fields of dark tobacco grown by members of this sect were found in 1928 to be entirely free from mosaic while their neighbors who used tobacco had the usual amounts of mosaic.

Mr. Harry Campbell of Ridgetown, Ontario, Canada, a representative of a tobacco company which contracts with farmers in the district to raise tobacco and who, consequently, has considerable supervision over the handling of the crops, stated to the senior writer in 1937 that he insisted that growers who had much mosaic one year take precautions necessary to raise tobacco relatively free from mosaic the next year before a contract could be signed. In addition to thoro clean-up about the plant-bed site, he furnished

Table 6. Amount of mosaic in plantings a month or more after setting, on the Campbellsville, Greenville, Princeton and Mayfield Experiment Fields.

		Healthy Plants	Mosaic Plants	Percent
Campbellsville				
1927-1933	No tobacco used by workers	42,000	0	0.0
1934	Plants from Station farm, Lexington, precautions taken in pulling	6,630	2	0.03
1935	Plants from Lexington; no record of pullers who chewed barn-cured tobacco washing hands	6,600	145	2.2
1936	Plants from Lexington. Precautions taken	6,600	0	0.0
Greenville				
1925-1937	Two men smoke Prince Albert or Granger	50,673	10	0.02
Princeton				
1926-1937	Pullers and setters washed hands and did not use tobacco	98,477	147	0.15[2]
Mayfield				
7-13-25	1 man, no tobacco used	2,520	0	0.0
7-19-26	1 man, chewed Apple Sun-cured plug	2,520	0	0.0
8-26-27	3 men, 2 chewed barn-cured tobacco	1,487	1,033	41.0
8-8-28	No record	2,369	151	6.0
7-14-29	1 man, smoked and chewed sterilized fire-cured tobacco. 2nd year in tobacco	2,569	31	1.2
7-15-30	Smoked barn-cured tobacco but not during operations, washed hands in creek, without soap, before pulling	2,494	26	1.0
8-15-31	Chewed barn-cured tobacco	1,900	626	24.8
7-4-32	Chewed sterilized Burley, 2nd year in tobacco	2,517	3	.1
8-12-33	Chewed sterile tobacco	1,933	11	0.6
8-15-34	Another man employed, uses no tobacco	2,520	0	0.0
8-14-35	Man uses no tobacco	2,520	1	0.04
8-17-36	Man uses no tobacco	2,500	1[1]	0.04
Summary	Men used sterile or manufactured tobacco	202,059	153	0.08
	Men chewed barn-cured tobacco	12,356	1,955	13.72

1 One mosaic observed early in summer not removed. Mosaic had spread to several others in same row.

2 Includes some field spread.

the growers with tobacco which he knew to be free from mosaic, for their personal use, and insisted on their roguing the few mosaic plants (less than .1 percent) which might appear. He stated that personally-used tobacco appeared to be the principal source of mosaic in the Harrow section in the types of tobacco with which he worked.

Field Surveys. In 1936 a field survey of mosaic was made in August and September, by the junior author, on farms picked at random. The results are given in table 7. The amount of mosaic varied greatly on adjoining farms and even in different fields on the same farms, under apparently similar conditions. Usually it was possible to explain such discrepancies by carefully questioning the grower or his workmen. A few examples from table 7 will illustrate. Grower 6 had 3 adjoining fields with 3, 4.2 and 27 percent mosaic. The workmen had been cautioned not to use barn-cured tobacco but one used some while pulling and setting the first 2 fields. After fields *a* and *b* were set, it was necessary to wait about 10 days until the plants left in the beds were large enough to set field *c*. This field set from the same beds from which *a* and *b* were set had 27 percent mosaic, evidently because of plant-bed infection which occurred at first pulling. Grower 7 set field *a* (3.2 percent mosaic) from his own bed and observed precautions to prevent infection from barn-cured tobacco. He set field *b* (33.3 percent mosaic) from the beds of grower 6 after the latter was thru setting. Grower 8 set all his crop of about 8 acres, except the last 25 rows at the end of the field, with plants from his own bed. He smoked manufactured cigarettes and did not use barn-cured tobacco. This portion of his crop had .6 percent mosaic and the 25 rows set with plants from his brother-in-law's bed, who chews barn-cured tobacco, had 25 percent mosaic. Grower 11 has successfully controlled mosaic for 3 years by forbidding the use of barn-cured tobacco and careful supervision of his workmen at setting time. In 1936 he set most of his crop from his own beds and at harvest had 1.1 percent mosaic. One field was nearly destroyed by wireworms and he reset this with plants from a bed of a neighbor who chewed barn-cured tobacco while pulling plants. He had 10.7 percent mosaic in this field. Thirty-three and 34 are adjoining farms and their

Table 7. Mosaic in tobacco fields in Kentucky in 1936. Fields were not in tobacco the previous year, except where indicated. Data between horizontal lines are from farms in the same neighborhood.

Grower	County	Type of tobacco	Percent mosaic present	Date of observation	Habits of grower and notes
1	Todd	dark fired	46.6	Sept. 7	Chewed barn-cured tobacco.
2 (a)	Todd	dark air-cured	18.0	Aug. 20	Chewed barn-cured tobacco.
(b)	Todd	dark air-cured	29.0	Aug. 20	Chewed barn-cured tobacco.
3 (a)	Todd	dark air-cured	21.4	Sept. 11	Chewed barn-cured tobacco.
(b)	Todd	dark fired	34.3	Aug. 28	Chewed barn-cured tobacco.
4	Todd	dark fired	.5	Aug. 28	Did not chew.
5	Todd	dark fired	4.8	Aug. 28	Did not chew but got some plants from neighbor.
6 (a)[1]	Todd	dark fired	3.0	Aug. 19	Cautioned men not to chew.
(b)	Todd	dark fired	4.2	Aug. 19	Grower thinks one man chewed.
(c)	Todd	dark fired	27.0	Aug. 19	Set after bed had been pulled over once.
7 (a)[1]	Todd	dark fired	3.2	Aug. 19	Smokes cigars.
(b)	Todd	dark fired	33.3	Aug. 19	Plants from 6 after latter was thru setting.
8 (a)	Todd	dark fired	.6	Sept. 10	Did not chew.
(b)	Todd	dark fired	25.0	Sept. 10	Plants from brother-in-law who chewed barn-cured tobacco.
9	Todd	dark fired	18.0	Sept. 10	Chewed barn-cured tobacco.
10	Todd	dark fired	34.9	Aug. 30	Chewed barn-cured tobacco.
11 (a)[1]	Todd	dark fired	1.1	Sept. 7	Did not use tobacco.
(b)	Todd	dark fired	10.7	Sept. 7	Got plants from neighbor who chewed barn-cured tobacco.
12	Todd	dark fired	38.0	Aug. 5	Chews barn-cured tobacco.
13	Todd	dark fired	4.4	Sept. 7	Did not chew barn-cured tobacco.
14	Todd	dark fired	28.5	Aug. 17	Chewed barn-cured tobacco
15	Christian	dark fired	12.5	Aug. 27	Field in tobacco 1935; chewed barn-cured tobacco.
16	Montgomery, Tenn.	dark fired	61.5	Aug. 27	Chewed barn-cured tobacco.

1 Attempted to follow directions given for controlling mosaic.

Table 7. (Continued)

Grower	County	Type of tobacco	Percent mosaic present	Date of observation	Habits of grower and notes
17 (a)	Todd	dark fired	9.7	Aug. 24	Chewed barn-cured tobacco.
(b)	Todd	air-cured	10.4	Aug. 24	Chewed barn-cured tobacco.
(c)	Todd	Burley	11.3	Aug. 24	Chewed barn-cured tobacco.
18 (a)	Todd	Burley	12.5	Aug. 24	Chewed barn-cured tobacco.
(b)	Todd	dark air-cured	16.6	Aug. 24	Chewed barn-cured tobacco.
19	Todd	dark fired	11.6	Aug. 6	Cautioned men not to chew.
20	Todd	dark fired	13.6	Aug. 14	Cautioned men not to chew.
21	Todd	dark fired	57.9	Aug. 27	Chewed barn-cured tobacco.
22 (a)[1]	Todd	dark air-cured	6.6	Aug. 27	Did not chew.
(b)	Todd	dark air-cured	14.0	Aug. 27	Set and cared for by cropper after his own was set. Latter probably used barn-cured tobacco.
(c)	Todd	dark fired	5.1	Sept. 11	Did not chew
23 (a)	Todd	dark fired	59.1	Aug. 20	Did not chew. Did much resetting after neighbors who chewed barn-cured tobacco had pulled plants from his bed.
(b)	Todd	dark air-cured	51.8	Aug. 20	Did not chew. Did much resetting after neighbors who chewed barn-cured tobacco had pulled plants from his bed.
(c)	Todd	dark air-cured	65.0	Aug. 20	Late setting after beds were pulled over.
(d)	Todd	dark fired	82.0	Aug. 20	Late setting after beds were pulled over.
24	Todd	dark fired	3.5	Aug. 27	Did not chew.
25 (a)	Todd	dark air-cured	33.9	Aug. 20	Chewed barn-cured tobacco.
(b)	Todd	Burley	22.6	Aug. 20	Chewed barn-cured tobacco.
26	Logan	dark air-cured	44.5	Aug. 20	Chewed barn-cured tobacco.
27 (a)	Todd	dark air-cured	81.5	Aug. 6	Watered bed with tobacco decoction.
(b)	Todd	dark fired	13.6	Aug. 6	Bed not watered with tobacco decoction. Chewed barn-cured. Both fields in tobacco for several years.
28	Todd	dark fired	90.0	Sept. 18	Chewed barn-cured tobacco. Had to reset several times.

Table 7. (Continued)

Grower	County	Type of tobacco	Percent mosaic present	Date of observation	Habits of grower and notes
29	Todd	dark fired	32.2	Sept. 14	Chewed barn-cured tobacco.
30	Todd	dark fired	.1	Sept. 14	Did not chew.
31	Todd	dark fired	.8	Aug. 30	Belongs to religious sect that forbids use of tobacco.
32	Todd	dark fired	6.7	Aug. 30	Chewed barn-cured tobacco.
33[1]	Todd	dark fired	51.3	Sept. 18	Did not chew, but got 75 percent of his plants from 3 neighbors after they were thru setting.
34 (a)	Todd	dark fired	2.5	Sept. 18	Smokes cigarettes.
(b)	Todd	dark fired	31.5	Sept. 18	Smoked barn-cured tobacco in a pipe. Beds of 33, 34-a, and 34-b contiguous.
35 (a)	Todd	dark fired	25.3	Aug. 19	Chewed barn-cured tobacco.
(b)	Todd	Burley	16.5	Aug. 19	Chewed barn-cured tobacco.
36	Todd	dark fired	.0	Aug. 19	Smoked manufactured tobacco (Stud) in pipe.
37	Todd	dark fired	28.0	Sept. 7	Chewed barn-cured tobacco.
38 (a)	Todd	dark fired	59.5	Aug. 28	Chewed barn-cured tobacco.
(b)	Todd	dark fired	64.3	Aug. 28	Chewed barn-cured tobacco.
39	Todd	dark fired	48.2	Aug. 28	Chewed barn-cured tobacco.
40 (a)	Todd	dark fired	2.8	Aug. 17	One man may have chewed barn-cured tobacco.
(b)	Todd	dark fired	8.8	Sept. 7	One man chewed barn-cured tobacco.
41	Todd	dark fired	46.5	Aug. 18	Chewed barn-cured tobacco.
42 (a)	Todd	dark fired	16.8	Aug. 18	Chewed barn-cured tobacco.
(b)	Todd	dark fired	43.0	Aug. 18	Plants grown on old bed site where tobacco plants were 5 ft. tall when plowed under in late fall.
43[1]	Todd	dark fired	0.0	Aug. 30	Did not use tobacco.
44 (a)	Todd	Burley	1.2	Aug. 19	Did not use tobacco.
(b)	Todd	dark fired	25.5	Aug. 19	Chewed barn-cured tobacco.

Table 7. (Continued)

Grower	County	Type of tobacco	Percent mosaic present	Date of observation	Habits of grower and notes
45	Todd	dark fired	0.0	Aug. 24	Chewed his own barn-cured tobacco but says he has had little or no mosaic for years.
46[1]	Todd	dark fired	0.0	Aug. 24	Did not use tobacco.
47[1]	Logan	dark fired	3.2	Aug. 20	Did not use tobacco. Wrapped one lot of plants in moist burlap bags, previously used to wrap damaged tobacco.
48	Logan	dark air-cured	40.0	Aug. 20	Chewed barn-cured tobacco.
49[1]	Logan	dark air-cured	.6	Aug. 20	Did not use tobacco.
50[1]	Logan	dark air-cured	1.6	Aug. 20	Brother to 48. Did not use tobacco.
51	Logan	dark air-cured	24.2	Sept. 7	Chewed barn-cured tobacco.
52	Logan	dark air-cured	90.0	Aug. 20	Watered plant bed with tobacco decoction.
53 (a)	Logan	dark fired	27.9	Aug. 22	Crew smoked barn-cured tobacco; field in tobacco 1935.
(b)	Logan	dark air-cured	38.7	Aug. 22	Crew smoked barn-cured tobacco; field in tobacco 1935.
54 (a)	Logan	dark fired	61.7	Aug. 22	Set by 53's crew. Plants mostly from 53.
(b)	Logan	dark air-cured	38.6	Aug. 22	Set by 53's crew. Plants mostly from 53.
55	Logan	dark air-cured	43.2	Aug. 27	Chewed barn-cured tobacco.
56	Logan	dark fired	46.4	Aug. 22	Chewed barn-cured tobacco. Field not in tobacco for at least 15 years.
57 (a)	Logan	dark fired	25.9	Aug. 4	Chewed and smoked barn-cured tobacco.
(b)	Logan	dark fired	28.2	Aug. 15	Chewed and smoked barn-cured tobacco.
58	Logan	dark fired	80.4	Aug. 3	Chewed and smoked barn-cured tobacco.
59	Logan	dark fired	23.2	Aug. 15	Chewed and smoked barn-cured tobacco.
60	Logan	dark fired	29.5	Aug. 22	Chewed and smoked barn-cured tobacco.
61	Logan	dark fired	5.0	Aug. 22	Did not chew. Man who chewed helped him for half day during setting.
62	Logan	dark fired	16.8	Aug. 29	Chewed barn-cured tobacco.
63	Logan	dark fired	39.8	Aug. 22	Chewed and smoked barn-cured tobacco.
64	Logan	dark fired	27.6	Aug. 15	Chewed and smoked barn-cured tobacco.
65	Logan	dark fired	61.2	Aug. 22	Chewed barn-cured tobacco.

Table 7. (Continued)

Grower	County	Type of tobacco	Percent mosaic present	Date of observation	Habits of grower and notes
66	Logan	dark fired	70.5	Aug. 15	Chewed barn-cured tobacco.
67	Logan	dark air-cured	58.6	Aug. 29	Chewed barn-cured tobacco.
68 (a)	Logan	dark air-cured	85.4	Aug. 22	Chewed and smoked barn-cured tobacco.
(b)	Logan	dark fired	80.6	Aug. 22	Chewed and smoked barn-cured tobacco.
69	Logan	dark fired	70.6	Aug. 3	Chewed barn-cured tobacco.
70	Logan	dark fired	84.0	Aug. 3	Chewed barn-cured tobacco.
71	Logan	dark fired	36.0	Sept. 11	Chewed barn-cured tobacco.
72	Daviess	dark air-cured	65.0	Aug. 11	Chewed barn-cured tobacco.
73[1]	Daviess	dark air-cured	2.0	Aug. 11	Did not chew. Brother of 72.
74	Daviess	dark air-cured	57.3	Aug. 11	Chewed barn-cured tobacco.
75	Caldwell	dark fire-cured	25.5	Sept. 4	Smoked cigarettes made of barn-cured tobacco.
76	Caldwell	dark fire-cured	28.0	Sept. 4	Chewed barn-cured tobacco.
Princeton Sub-station[1]	Caldwell	dark fire-cured	.6	Sept. 4	Did not chew barn-cured tobacco.
77 (a)	Christian	dark fire-cured	12.0	Sept. 9	Chewed barn-cured tobacco.
(b)	Christian	dark fire-cured	3.0	Sept. 9	Handled by tenant who did not use barn-cured tobacco.
78	Christian	dark fired	1.0	Sept. 9	Did not chew barn-cured; occasionally smokes barn-cured 3-yr.-old Burley in pipe.
79	Logan	dark fired	38.9	Aug. 25	One man who pulled most of plants chewed barn-cured tobacco.
80	Logan	dark fired	20.5	Aug. 25	Chewed barn-cured tobacco.
81	Logan	dark fired	.7	Aug. 25	Did not use tobacco.
82	Logan	dark fired	6.0	Aug. 25	Did not use tobacco.
83[1]	Cheatham, Tenn.	dark fired	.5	Sept. 15	Rogued mosaic plants as soon as they appeared.
84[1]	Cheatham, Tenn.	dark fired	1.5	Sept. 15	Son did all handling of mosaics. Nobody else allowed to touch them.

plant beds were contiguous. Thirty-three did not allow his workmen to use barn-cured tobacco but on account of drouth, 80 percent of his first setting died. He reset with plants from the beds of 3 neighbors, all of whom used barn-cured tobacco. He had 51.3 percent mosaic. Thirty-four had 2 fields handled by 2 tenants each of whom had his own bed. Field *a*, cared for by a man who used commercial cigarettes only, had 2.5 percent mosaic, while field *b*, cared for by a man who smoked barn-cured tobacco in a pipe, had 31.5 percent. The same cropping system was used by 33 and 34 and the fields were close to each other. Thirty-five and 36 are adjoining farms and their beds were parallel. The former, whose workmen used barn-cured tobacco, had 25.3 and 16.5 percent mosaic, respectively, in dark fire-cured and Burley tobacco. The latter, just over the fence, who smoked granulated manufactured tobacco in a pipe, had no mosaic at harvest. Seventy-two and 73 are brothers whose farms are in the same neighborhood. Seventy-two, who chews barn-cured tobacco, had 65 percent mosaic while his brother, who did not use tobacco, had 2 percent. On 13, or 15.5 percent, of the 84 farms studied, the grower was attempting to control mosaic under the direction of the county agent or crop specialist. Considering the fact that the observations were all made near cutting time, the degree of control obtained is remarkable.

Only three of the fields studied had been in tobacco the previous year. This fact eliminates nearly completely the possibility of soil carry-over. Nevertheless the amount and distribution of mosaic are probably as great as is commonly found in regions where tobacco commonly follows tobacco, or greater. The fact that, where efforts were made to control mosaic by preventing infection from the hands of the workers, the disease was largely prevented tends to prove that contaminated hands were the principal source of infection where it occurred.

In 1937 a similar survey was made in several counties in western Kentucky just previous to harvest. The observations made on 162 fields on which tobacco had not been grown in 1936 were arranged in three groups according to the conduct of the workers in the use of tobacco while tending plant beds and setting plants. The men of the first group chewed and smoked barn-cured tobacco; those of the second group were men who ordinarily used barn-

cured tobacco but changed to manufactured tobacco when handling tobacco plants, and men who habitually used manufactured tobacco or manufactured cigarettes; while those of the third group claimed they used no tobacco. Table 8 and figure 1 show the re-

Table 8. Incidence of mosaic as related to use of viruliferous tobacco by workers, observed in 162 fields, in 1937.

Barn-cured tobacco used		No barn-cured tobacco used		
			Manufactured tobacco or cigarettes used	No tobacco used
Percent of mosaic plants	No. of fields	Percent of mosaic plants	No. of fields	No. of fields
0.1	3	0.00	5	14
1	2	0.01	2	—
5	1	0.04	1	1
6	1	0.05	1	—
7	3	0.10	4	4
8	5	0.20	1	1
9	4	0.30	4	5
10	3	0.40	1	1
11	4	0.70	1	—
12	6	1.00	2	2
13	4	1.10	—	2
14	2	1.40	2	—
15	1	1.50	3	—
16	4	1.80	5	—
17	3	2.40	2	—
18	3	2.50	1	—
19	3	2.60	1	1
20	3	3.40	1	—
21	2	3.70	—	1
22	2	4.00	1	—
23	2	4.20	—	1
24	2	5.00	2	—
29	2	5.10	1	—
30	1	6.00	2	—
32	2	6.20	1	—
33	2			
35	3			
36	1			
38	2			
39	1			
41	1			
42	1			
46	1			
55	1			
60	1			
67	1			
83	1			
90	1			
Total	85		44	33

Table 9. Range and average percent of mosaic in fields (a) where attempts were made to control tobacco mosaic by prohibiting the use of barn-cured tobacco by workers in the bed and at setting; (b) where no attempt was made to control mosaic but no barn-cured tobacco was used thruout the season, and (c) in fields where barn-cured tobacco was smoked or chewed by the workers thruout the season. Records were made shortly before harvest, 1937.

	Number of fields	Range of mosaic percent	Av. mosaic percent
Use of barn-cured tobacco prohibited	31	0.0— 9.0	2.5
No attempt to control but workmen either used no tobacco or used manufactured tobacco thruout the season	41	0.0— 4.2	0.46
Workmen chewed or smoked barn-cured tobacco[1]	31	6.7—83.0	23.0

1 These are the first 31 fields recorded where workmen used barn-cured tobacco.

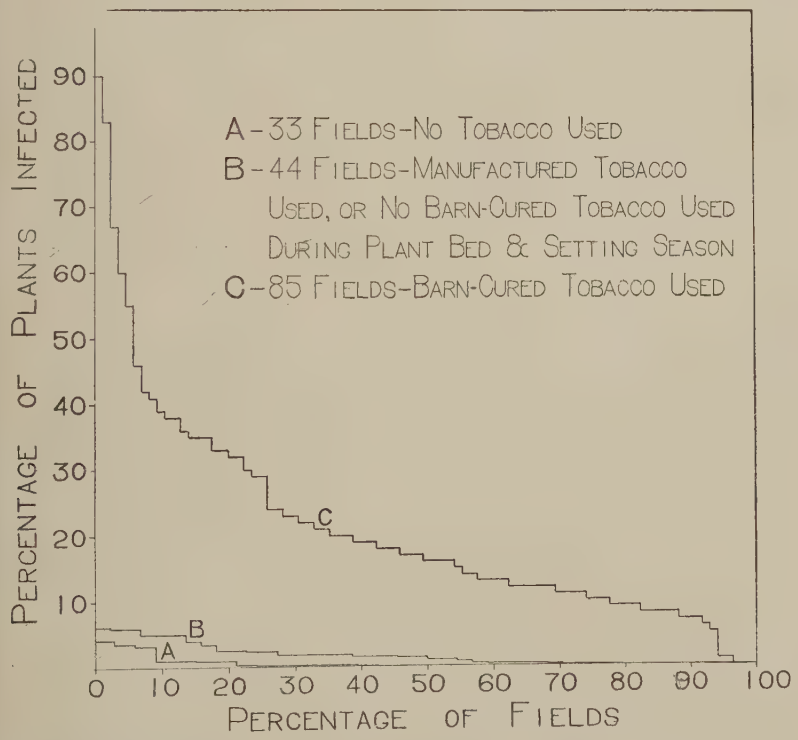

Figure 1. Incidence of mosaic as related to use of viruliferous tobacco by workers, observed in 162 fields, in 1937.

sults. The lower curve (A), in the figure, is based on 33 fields handled by men who used no tobacco thruout the season. The area within the curve when compared with the entire square represents the proportion of the crop, on an average (.55 percent), which might be expected to be infected with mosaic at cutting time if all growers in an area used no tobacco thruout the season. The middle curve (B) is based on 44 fields handled by men who used manufactured tobacco or were in the habit of using barn-cured tobacco but claimed to have used none while working in the plant bed or setting plants. The small average amount of mosaic (1.6 percent) in these fields may have originated from the hands of the workers which were not thoroughly washed, or which may have become recontaminated from bits of tobacco still in their pockets or infection may have occurred from the hands of men who used barn-cured tobacco during the summer. The upper curve (C) is based on 85 fields cared for by men who used barn-cured tobacco for chewing or smoking thruout the season. The portion of the entire square (20.9 percent) bounded by this curve represents the part, on an average, of the tobacco which may be expected to be infected with mosaic by cutting time if the fields under consideration have been cared for by men who chew or smoke barn-cured tobacco. These results seem to give proof that in fields where tobacco does not follow tobacco the principal source of mosaic infection is barn-cured tobacco used by workmen.

On 11 fields tobacco followed tobacco and on three of these fields tobacco plants lived thru the mild winter of 1936-37. Some of these plants were found to have mosaic in the spring of 1937 and seemed to have been a source of infection for plants set in 1937, because on two of the farms where 14.7 and 17 percent mosaic was found following tobacco similarly treated fields not in tobacco the previous year had .4 and .1 percent mosaic, respectively. On the other fields the amount of mosaic was large or small depending upon the habits of the workmen with respect to the use of tobacco.

Twist Chewing Tobacco. In 1937, 35 samples of twist chewing tobacco, prepared from barn-cured tobacco, were collected from as many tobacco growers. Samples of these weighing .9 gram were ground in a mortar, 9 c.c. of water was added and the tobacco was allowed to soak for 1 hour. Then inoculations were made on

Scotia bean leaves and on leaves of *Nicotiana glutinosa* and F_1 hybrids of it and White Burley tobacco. Thirty of these samples, or 85.7 percent, were found to carry the virus. It is obvious that the majority of tobacco growers who chew or smoke barn-cured tobacco while handling plants are also handling viruliferous tobacco.[1]

Manufactured Tobacco. Manufactured tobacco sometimes is viruliferous and has therefore been considered by some investigators to be a rather common source of infection but the facts so far obtained hardly justify this conclusion. In 1927, Valleau and Johnson (21) obtained the following results with 44 brands of tobacco tested:

Tobacco tested	Number of brands tested	Number of brands contaminated	Number of samples contaminated	Number of samples mosaic free
Plugs	23	4	10	33
Scrap	5	0	0	5
Twist	2	0	0	3
Snuff	1	0	0	1
Cigarettes	7	7	11	1
Granulated smoking	5	5	5	0
Plug cut	1	0	0	1
Total	44	16	26	44

These results proved that commercial tobaccos sometimes carry the virus but it was pointed out that, as only four brands of plug tobacco of 23 tested carried the virus, and three of twist, five of scrap, and one of snuff were found to be free, manufactured tobaccos were not likely to be common sources of infection.

In 1928, 15 brands of cigars were tested and 7 were found to carry the virus (5). The same year 11 brands of plug chewing tobacco and one lot of barn-cured tobacco were made into separate decoctions with water and the decoctions rubbed on approximately 60 plants each, which were then set in the field. Every fifth row of plants from the same bed was pulled and set with clean hands. Twenty-six days later the following results were obtained:

	No. of Plants		
	Set	Mosaic	Percent Mosaic
Brand A	60	6	10.0
Brand B	47	3	6.4
Other nine brands	496	0	0.0
Check plants, clean hands	375	0	0.0
Barn-cured tobacco	65	41	63.1

1 Pinckard has recently shown that the tobacco mosaic virus is not inactivated by a temperature of over 190° F. for 7 hours during flue curing, hence flue-cured tobacco may be a source of infection if it is used by growers while handling living plants. (Abst. in Phytopathology 28: Jan. 1938.)

These results demonstrated that not only were most of the brands of plug tobacco free from mosaic but where it was present the concentration was very low.

The same year 15 brands of smoking tobacco in cans were found to carry virus but it was difficult to contaminate the fingers by handling the tobacco because of the glycerine and other materials added or because of low virus concentration.

Busch and Wolf (6) studied 45 brands of manufactured tobacco including 10 of granulated pipe tobacco, 7 of cigarettes, 11 of snuff and 17 of chewing tobacco. Of the 45 brands studied only 2 brands of chewing tobacco and 2 of snuff caused mosaic. In 1937 J. Johnson (14) reported that cigars, cigarettes and pipe tobacco carried the virus but 10 brands of snuff and chewing tobacco were found to be free.

Because of results such as these, we have not hesitated to recommend the use of plug and twist tobacco for chewers, and the men have used manufactured plug (Star) on the Station farm several years while pulling and setting, with good results. We have good evidence that at least 2 brands of canned smoking tobacco are safe to use. The Greenville soil experiment field has been cared for for several years by two men who smoked Prince Albert and nothing else, until 1934 when they changed to Granger. They take no precautions to prevent mosaic in the plant bed and field except when extra help is hired and have never been troubled with mosaic except occasionally following a field meeting attended by tobacco users (table 6).

Cigarettes commonly carry the virus, but because of the cover of paper and the treatment of glycerine and other materials which the tobacco receives, there is little chance that one's fingers would become contaminated from them. Field observations where cigarettes were used by the worker, confirm this view. Granulated smoking tobaccos also carry the virus but do not seem to contaminate the hands while filling a pipe or rolling cigarettes.

Nine fields cared for by men who used manufactured granu-

lated smoking tobacco were observed when about ready to cut. The percentage of mosaic plants were as follows:

	Percent of mosaic plants
Brand A, 2 fields	0.0
Brand B, 1 field	0.0
Brand C, 3 fields, respectively	0.0 0.2 1.5
Brand D, 1 field	0.3
Brand not recorded, 2 fields, each	0.1

Fukushi (9), after a study of mosaic in commercial brands of pipe tobacco commonly smoked by Japanese tobacco growers, stated that "It is highly probable that tobacco growers may spread the mosaic disease of tobacco in the operations of transplanting, topping and weeding, etc. of the tobacco plants with hands contaminated with the virus during smoking the pipe tobacco."

The contention (14) that manufactured tobacco, because of blending, is more likely to contain virus than barn-cured tobacco, is hardly valid, for the manufacturing processes tend either to reduce actual virus concentration as in plug and twist tobacco or tend to greatly reduce the chance that the fingers of the workers will become contaminated, as cigarettes and pipe tobaccos. On farms where mosaic is constantly a problem it would be difficult to select cured tobacco for chewing or smoking which did not contain virus. Where but little mosaic is present from year to year but little infection would be expected from the use of the nearly virus-free tobacco used by the workers. Many brands of commercial tobacco have a very low virus concentration or none whatever because of the heating to which they are subjected altho the original tobacco may have been viruliferous because of blending.

Until proof has been produced that manufactured tobaccos are actually a common source of tobacco mosaic, they may be consid-

Table 10. Distribution of viruses in Physalis sp. and Solanum carolinense growing in grass plots on the Experiment Station farm.

	Plants
Total examined	633
No virus found	445
Tobacco mosaic	132
Etch	4
Cucumber mosaics	11
Ringspot	3
Virus not determined	38

Table 11. Distribution of tobacco mosaic in plantings on the Station farm, Lexington, 1930 to 1937, showing gradual increase in mosaic during the summer but satisfactory commercial control where men were required to wash their hands and use sterile tobacco or manufactured plug while pulling and setting. Tobacco had not been grown on the land for at least 4 years. Plant beds were mosaic free.

Year	1930	1931	1932	1933	1934	1935	1936	1937
Number of plants set	36,168	40,900	32,712	31,500	17,424	14,686	12,800	15,542
Number of mosaic plants, 1st count	35	2	241	2	12	7	382	215
Number of mosaic plants, 2nd count	76	41	468	558	275	10	—	145
Number of mosaic plants, 3rd count	—	205	—	706	2076	—	—	195
Number of mosaic plants, 4th count	—	—	—	—	—	—	—	125
Percent of mosaic plants after topping	—	4.4	—	5.8	12.7	—	—	—
Percent of mosaic plants after cutting	.	—	31.0	—	—	1.4	.93	.64

[1] About ½ of these were resets, evidently pulled and set with contaminated hands.
[2] 18 from 1 chew of tobacco.
[3] Dry season; tobacco not topped until cutting time.
[4] 5,300 plants counted.
[5] Plants removed.
[6] In 108 rows.

ered relatively safe for use by workers in tobacco except while weeding or otherwise handling plants in the bed before pulling time.

LIVING PLANTS AS A SOURCE OF MOSAIC

Infected perennial weeds and overwintering annuals cannot be disregarded as possible sources of infection. Perennial solanaceous weeds growing in pastures or other grass plots in the vicinity of fields frequently set with tobacco are often found to be infected with the tobacco mosaic virus even tho the weeds may be several hundred feet from the tobacco fields (table 10). Each year mosaic-affected tobacco plants appear in the Station plantings which cannot be accounted for. For example, in 1934 the 27 mosaic plants found were rogued at the second count (table 11). At the time of the third inspection 21 days later, 207 mosaic plants were found, scattered at random in 108 rows. A similar condition existed in 1937 (table 11). The source of infection of these plants, which were distributed rather evenly over the field, is not known.

In all the plots on the Station farm cucumber mosaics, etch, veinbanding and ringspot are rather generally distributed thru the crop. These viruses, except veinbanding, are found in solanaceous weeds and are probably spread to tobacco from them. It is possible that the insects responsible for weed infection from tobacco may be responsible for some of this summer infection of tobacco with mosaic, altho workers may have been the source; and it is not impossible that during cultivation the tools may become contaminated from infected weeds in the field and spread the virus to tobacco. If infection occurs from weed hosts it is not extensive.

INSECT TRANSMISSION OF MOSAIC

The problem of insect transmission of tobacco mosaic has never been thoroly studied. Allard (2) demonstrated that the peach aphis (*Myzus persicae* Sulz) and other species of aphis could transmit a virus which he thought was that of tobacco mosaic, from tobacco to tobacco. Miss Hoggan (10), in a series of carefully conducted studies, demonstrated, she believed, that *Myzus persicae* is incapable of transmitting the tobacco mosaic virus, but regularly transmits the cucumber mosaic virus. She demonstrated, however, that three other species of aphis, *Macrosiphum solanifolii, Myzus cir-*

cumflexus and *M. pseudosolani* were each able to transmit the strain of tobacco mosaic studied, from tomatoes to tobacco but not from tobacco to tobacco. The strain of virus used was apparently an unusual one, for it caused systemic mosaic in tobacco and *Nicotinia glauca* but produced systemic necrosis in pepper and *Physalis pubescens.* In nearly all varieties of pepper most strains of the virus cause only mottle. The fact that Miss Hoggan demonstrated aphis transmission of two strains of the tobacco mosaic virus to tobacco proves that these species are carriers of the virus and makes it appear reasonable that in nature some species of aphids and perhaps other insects may play a part in dissemination of mosaic from tobacco to solanaceous weeds and from the weeds to an occasional tobacco plant even tho they do not transmit the disease from tobacco to tobacco in the field. In view of the fact that certain aphids become contaminated with the tobacco mosaic virus and are then capable of transmitting it to tobacco, it cannot be concluded that they play no part in initial field infection, as has been the tendency recently. A virus so readily transmitted mechanically as tobacco mosaic might well be introduced into tobacco fields from infected weeds by some of the biting insects which commonly visit tobacco.

Insect transmission, if it occurs, is probably a minor factor in outbreaks of mosaic, but it may eventually prove a constant source of trouble on farms where weeds are infected and where the grower is making every effort to eradicate the disease but finds it cropping out over the field in individual plants which may become centers of spread by other means.

CONTAMINATED SOIL NOT A COMMON SOURCE OF MOSAIC

In summarizing his investigations on mosaic, Mayer (17) stated in 1886 that "the dissemination of the disease-producing material must be looked for in the soil of tobacco plantations and hotbeds; because permanent plantations are particularly exposed to the disease. However, an instance of its transmission by soil has not been established."[1] Nevertheless he recommended a change in plant-bed soil where mosaic is a factor, roguing of plants in the field and complete removal of all mosaic plants from the field at

1 Translation by the authors.

the end of the season so that no mosaic material would remain on the land. This is perhaps the first suggestion in the literature that soil is a factor in carry-over but it should be remembered that it was not based on experimental or observational data.

In 1929 Johnson and Ogden (12) revived the theory of soil contamination as an explanation of initial infection of tobacco grown in fields where tobacco was heavily infected the year before. They gave no explanation for infection in fields set with tobacco for the first time and disregarded completely the part which man might play in causing initial infection in the plant bed and field while weeding and pulling plants, if his hands were contaminated with virus from chewing or smoking tobacco or from otherwise handling viruliferous material. They assumed that because mosaic virus could be obtained from about the dead roots of infected plants in the spring, this must be the chief source of mosaic in the field. The possibility that cucumber mosaic and other common virus diseases might be present in their plots and be mistaken for tobacco mosaic was not given consideration altho it was known at that time that cucumber mosaic was a common disease in tobacco fields located near garden plots (22, 20, 5). It has since been shown that cucumber mosaic was present in at least a portion of their plots and it was probably mistaken for tobacco mosaic in their studies on the effect of curing on the longevity of the tobacco virus (14). Johnson and Ogden proved beyond reasonable doubt that the tobacco mosaic virus can and does persist over winter in the dead roots of tobacco plants and can be recovered from adjacent soil in which visible roots are not present.

In 1937, J. Johnson again stressed soil contamination as a source of initial infection. In the annual report of the Wisconsin Agricultural Experiment Station, the statement is made that "Thus far there is known only one effective means of controlling mosaic, and that is to refrain from planting tobacco on heavily infested fields" (8). As Johnson's paper (14) was published at a time when an aggresive and successful mosaic-control program was under way in some of the southeastern tobacco-growing states, his statements need careful consideration. The field evidence given in his paper was observational and was collected between 1926 and 1932. It is

open to the same objection as the earlier observations of Johnson and Ogden, and in addition insufficient recognition was given to the possibility of spread during the summer by machinery used in cultivation and to the possibility of direct infection by man either as a result of handling an occasional infected plant and then handling healthy ones, or directly from hands contaminated by tobacco used for chewing or smoking, while hoeing, worming, etc. He states that "the present status may be well represented by Wolf's recent discussion of tobacco mosaic in the flue-cured tobacco district of the United States. In a three year survey it was found that the mosaic in 125 fields out of 229 examined could be traced to infested soil alone." By infested soil Wolf evidently meant a soil in which were present living infected roots, as he states (25) "mosaic virus may retain its infectivity in tobacco stubbles, as shown by the fact that in the spring mosaic suckers may develop on stubbles that have remained alive. In 125 of the 229 fields observed, the virus overwintered in tobacco stubbles." This certainly does not represent "the present status" in the more northern states where tobacco roots are killed by winter freezes. Neither is it in accord with the statement (14) that "some overwintering may occur in perennial hosts, or in tobacco or other annuals where killing frosts do not occur, but this potential source of infection is no longer regarded as of much importance by most investigators." Lehman's (15) field studies confirm Wolf's view as to the method of overwintering of the virus in North Carolina. Johnson states that Lehman (15) "apparently attaches somewhat less importance to direct infection from either the soil or the use of infected tobacco by workers, but finds high percentages of mosaic spread resulting from cultivation." Lehman's chief contribution, aside from demonstrating rapid field spread and its control by roguing, appeared to be that by eliminating the virus from the hands and clothes of workers, mosaic could easily be controlled even when tobacco was set in fields which had grown an infected crop the year before. Lehman states "The careless use of tobacco in chewing and smoking while handling young plants, as in weeding beds, etc. is responsible for initial infections which may develop to large proportions by harvest."

Johnson concludes "that the soil is a very common source of

primary infection." The reasons for this conclusion are as follows: "1. Previously infested fields regularly develop a considerably higher percentage of mosaic than do newer fields (table 2); 2, except for such mosaic as is plainly due to infection before or at the time of transplanting, the disease develops gradually in the field during the early growing season in the absence of other sources of infection and dissemination (table 1); and 3, the virus regularly persists in the field soil in sufficient quantity and for sufficient time to account for this infection (table 10)." A critical examination of these reasons shows that his conclusion cannot be accepted. Reason 1 is open to question in view of carefully conducted tests of Lehman which demonstrate clearly that heavily-infested fields may produce practically a virus-free crop the next year if certain simple precautions are taken to prevent initial infection by workmen and spread in the field by tools. It is open to further criticism that in Kentucky where tobacco rarely follows tobacco, mosaic is often a serious problem in fields set to tobacco for the first time (tables 5, 7 and 9). Further, he apparently gave no consideration to the possibility of infection while weeding, pulling, and setting. Reason 2: Lehman has shown that where care is not taken to prevent spread in the field, there is a gradual increase in mosaic during the summer, but where spread is prevented by roguing before cultivation, gradual increase does not occur. The writers have some evidence of a gradual building up of infection in fields not in tobacco before and where the first mosaic plants were removed soon after growth commenced. Wolf (25 p. 164) considered that the gradual increase of mosaic during the summer was not due to soil contamination but was the result of spread by man himself in caring for the crop. Johnson assumes "the absence of other sources of infection and dissemination." Reason 3: While the virus may persist in the soil from one crop to the time of setting the next crop, no one has produced acceptable evidence that more than an extremely low percentage of mosaic ever actually originates directly from this source; and evidence cannot be forthcoming on this point until all chance of infection from the bed, during pulling and setting, and spread by operations in the field are eliminated, and the study is confined entirely to the tobacco mosaic virus.

Wolf made a careful study of the epiphytology of tobacco mosaic in plant beds and fields in North Carolina covering the years 1928, 1929, and 1930 (25). He observed early is the course of his study that mosaic occurs in the seed bed on seedlings of sufficient size for transplanting. He found infected seedlings in 108 of 584 beds examined. This seems to be sufficient evidence to disprove Johnson's claim (14) that "visible symptoms of mosaic are rare even on infected seedlings in seed beds at the time of transplanting." Infection in only 1 of the 108 beds could possibly be attributed to infected seed-bed soil as but one bed was located on an old site. Wolf concluded that manufactured tobacco used by the grower constituted the most probable source of the introduction of the virus in 105 of 108 seed beds in which infection was found. If the 584 beds are representative, then infection in about 20 percent of the fields in North Carolina can be explained by infection originating from the hands of the workmen in the beds before pulling commences.

Wolf made observations on the source of mosaic in the field in 229 fields examined during three seasons. He concluded that infection could be traced to seed beds alone in 24, to infected field soil alone (living or partially living overwintered tobacco stubble) in 125 and to both diseased seedlings and infected soil in 63. In 17 the source of the inoculum could not be determined, altho he suggested that it might have been the hands of the workers which had become contaminated thru their having used manufactured tobacco. His conclusions cannot be accepted for the reason that the criteria used to determine sources of field infection left out what appears to be the most common source of infection; namely, infection while pulling and setting. It seems obvious that, if 20 percent of the beds were infected before pulling, plants pulled from mosaic-free beds could become infected from the same source that caused infection in other beds. He states "infected soils alone were regarded as the source when the seed beds from which the crop was planted were mosaic free, and where such fields had borne a mosaic-affected crop during the previous year." Infection in the 125 fields attributed to soil alone (overwintering plants), and the 17 which

could not be determined, may have come from the hands of the men who pulled and set the plants, altho it is entirely probable that some infection in the former may have originated from overwintered plants. It should be kept in mind that beds may be cared for by men who for one reason or another do not contaminate any plants, but at pulling time other laborers may be hired for pulling and setting who use tobacco in one form or another and who may therefore infect plants while pulling and setting them. Every plant set in the field is handled at least twice individually in the process of pulling and setting at which times they are subject to infection if the hands of the workers are contaminated. This may account for field infection and also for mosaic which frequently appeared in beds free from infection at pulling but which were found by Wolf to be infected following first pulling. Wolf concluded that his evidence "shows that the careless use of manufactured tobacco constitutes the most common source of inoculum for mosaic in the flue-cured areas."

Lehman (15) conducted well planned and executed field experiments during three years to determine the part which overwintering of the virus in the field played in subsequent field infection in North Carolina. He recognized the possibility of infection while weeding, pulling and setting by workers who used tobacco, and he tried to prevent it. All plants of certain plots were inoculated in August of one year, and the diseased plants either disked in the fall, allowed to stand over winter when they were disked, plowed under in fall or spring, or removed from the land in fall or spring. In 24 plots, or all in which tobacco followed tobacco which was infected 100 percent, and to some of which additional infected stalks were added, 5834 plants were grown. In these plots 108 plants or 1.8 percent, developed mosaic by about the middle of August or nearly harvest time. Diseased plants were removed when found and the plots cultivated only following removal. It seems evident that in North Carolina overwintering in roots or soil is a very minor factor, if spread from infected plants can be prevented, and one which, as both Wolf and Lehman have shown, can be largely overcome by fall removal, fall disking, or deep plowing in the spring, and roguing before cultivation (15, 24). Lehman's results give very little sup-

port to the theory of soil carry-over, but do give proof that if a sufficient amount of virus-carrying material is disked into the soil in the spring, some plants will become infected from this source by topping time. He concluded that "few, if any, of the more serious diseases of this crop may be more easily or more effectively controlled by means easily within the reach of every grower. The occurrence of a high percent of this disease in any field may usually be ascribed to lack of understanding of the nature of the disease and of certain simple ways by which it may be controlled or to carelessness in application of preventative measures." This conclusion seems to be entirely justified by facts now known about mosaic.

Anderson (3) reported in 1936 that in the Connecticut Valley where tobacco is grown year after year on the same land, there are "many indications that at least part of our bad infestation may start from the same source" (chewing and smoking tobacco used by workmen).

Soil Carry-over Studies in Kentucky. Estimates made independently by ten of the more experienced county agricultural agents in tobacco-growing counties in Kentucky, indicate that not over 10 percent of the crop is grown on land which was in tobacco the previous year. This largely eliminates soil carry-over as a possible source of initial infection in the State. In spite of this, mosaic may be an abundant and serious disease (tables 1, 3, 4, 7, 9).

In 1931 a study was begun to determine the extent to which soil carry-over might be a factor in mosaic infection in Kentucky where fields are used for tobacco two years or more in succession. A field was used in this study which had been cropped to tobacco continuously for more than 15 years. From one part of the plot mosaic plants, when found, were removed immediately. In the other part the plants were inoculated with mosaic when they approached the blooming stage. Except one year, strains of mosaic were used which could easily be recognized the following year. Inspection of the plots was made at intervals from about 18 days after setting until the tobacco was about three-fourths grown when the mosaic plots were again inoculated for carry-over studies the following year. Mosaic plants were removed as soon as found, to

Table 12. Soil carry-over studies of yellow mosaic, mosaic burn, and four strains of green non-burning mosaic. Figures show the number of plants infected with the same virus as was present the previous season. Figures and letters in parenthesis show the number of plants infected with some other virus, and its kind; b = mosaic burn, y = yellow, and g = green mosaic.

Year	Date set	Plot number	Total plants	Treatment previous year	Mosaic plants found and removed at each inspection						Infection attributable to soil
					First	Second	Third	Fourth	Fifth	Sixth	
1933	5-31	1	894	Mosaics removed	0	(7[1])	(11)	(4)	(6)	—	0
		2	436	Yellow mosaic	(1g)	(2g)[2]	(3g)[2]	(1g)[2]	0	—	0
		3	353	Green mosaic	0	0	(1y)	1	0	—	1
1934	5-29	1	857	Mosaics removed	0	(2g)	(3g)	0	—	—	0
		2	430	Yellow mosaic	0	0	1	0	—	—	1
		3	428	Severe green	0	(1y)	0	0	—	—	0
1935	6-1	1	1,024	Mosaics removed	0	(3g)	0	0	—	—	0
		2	510	Yellow mosaic	0	1(3g)	(1b)	0	—	—	1
		3	514	Mosaic burn	0	5[3]	3	5	—	—	8(5[3])
1936	5-25	1	835	Mosaics removed	(1y)	0	0	0	0	0	0
		2	412	Yellow mosaic	(2g)	(6g)[2]	0	0	(1g)	0	0
		3	406	Mosaic burn	0	0	1	(1g)	(2g)	(1g)	1
1937	6-7	1	420	Mosaics removed	0	(1b)	0	0	0	0	0
		2	449	Green mosaic	(1y)	0	0	2	0	0	2
		3	417	Yellow mosaic	(1g)	0	0	1	1	0	2
		4	465	Mosaic burn	0	0	0	0	0	0	0

1 Not removed until next inspection. 2 All of same type and all in group. 3 Type not recorded.

prevent spread. There is little evidence from four years' tests that infection from soil is other than a very minor factor (table 12). In 1935, of the 2.5 percent of the plants in the mosaic-burn plot which developed mosaic, 1.5 percent were mosaic burn which almost certainly came from virus carried over from the previous year's crop; the kind of mosaic in the other 1 percent was not recorded. This was the only year, however, when a possibly significant amount of mosaic occurred which could be attributed to soil carry-over.

While there is no doubt that the mosaic virus is present in the dead roots of tobacco plants in the spring of the year following a heavily infected crop (table 13), the probability that infection will be caused in a new crop set in the land needs consideration. Before a crop is set it is common practice to stir the ground with a disk as often as is convenient. After the crop is set the ground is cultivated at least once before the plants attain much size. Frequent stirring of the soil stimulates biological activity as evidenced by the high nitrate content of tobacco soils at setting time. High biologic activity tends to reduce virus concentration, and Lehman (16) and J. Johnson (14) have pointed out that drying the soil quickly inactivates the virus. The combination of a high biologic activity and drying of the surface layer of soil following frequent stirring during the spring and early summer should result in a relatively sterile surface layer as far as virus is concerned. It is not surprising, then, if infection does not commonly occur thru roots as seems to be agreed, that infection of plants in contaminated soil is rare.

A critical study of the published evidence on soil carry-over indicates that, except in fields in which the stubble lives thru the winter, and where tobacco trash is applied to a tobacco field in the spring, Allard's conclusion of 1914 is still valid. He stated "Although the opinion seems to be quite generally held that the refuse of mosaic plants plowed into soil may be responsible for the disease, there is little evidence to support this view" (1).

INFECTION FROM CONTAMINATED MATERIAL ADDED TO THE SOIL BEFORE SETTING

Infected stalks or stalks and leaves were saved from the overwintering experiment each year and added to plots on land which

had not grown a crop of tobacco for several years. Proper precautions were taken to see that only mosaic-free plants were set. The chopped or ground stalks and leaves were scattered on the plots before the last disking and were disked in lengthwise of the plots. If infection occurred, the type of mosaic must correspond with that of the virus added before it was considered proof of infection from the material added. Mosaic plants were removed at each inspection to prevent spread. Inspections were made at fairly regular intervals thruout the growing period. The results obtained were strikingly different from those where infected stubble alone was the source of contamination as infection was high each year (table 14). These tests show that if the virus is present in the upper soil layer, infections will occur up to topping time at least. Infection was higher when the stalks and leaves were ground in a hammer mill than when chopped into large pieces.

Attention should be called to the 1937 test in which the plants were set by hand with no precautions to prevent spread of infection at setting time from plots to which ground mosaic material had been added to those to which none had been added. Most of the infections in the untreated plots occurred early in the experiment and were evidently caused by contamination of the hands of the workers from contact with the ground material added to the soil of a treated plot.

Table 13. Infection of tobacco plants from virus overwintered in field soil. Soil from around tobacco plants that had been inoculated the previous summer with yellow or green mosaic was made into a thin paste and rubbed on the leaves of plants which were then set in flats of the same kind of soil.[1]

Date of collection of soil and transplanting	Plot from which soil was obtained	Number of plants set	Mosaic plants found	
			Yellow	Green
March 25	Contaminated	42	1	10
April 6	Contaminated	80	5	10
April 6	Uncontaminated	78	0	0
May 16	Contaminated	122	3	5
May 16	Contaminated[2]	56	0	0
May 16	Uncontaminated	50	0	0
May 30	Contaminated	113	2	3
June 11	Contaminated	38	0	4

1 A total of 36 healthy plants were rubbed with composite samples of bits of leaves from each plant before transplanting to be certain of their freedom from mosaic. These plants all remained healthy. 2 Plants not inoculated but set in contaminated soil.

Table 14. Incidence of tobacco mosaic in tobacco planted in ground in which viruliferous tobacco stalks and leaves containing mosaic burn (b), yellow mosaic (y), and green non-burn virus (g), had been mixed, immediately before setting, on different plots. Numbers alone show the number of mosaic plants found of the kind applied. Numbers and letters in parentheses show the number and kind of mosaic plants of other kinds found.

Rows	Number of plants set	Kind of virus in added material	Number and kind of mosaic plants found in each inspection								Percent of mosaic plants attributable to added material
			1st	2nd	3rd	4th	5th	6th	7th	8th	
	1933. Plants set May 23										
3-8	276	None	0	0	0	0	0	—	—	—	0.0
9-14	264	Yellow mosaic[1]	0	2(1g)	2	0	(1g)	—	—	—	1.5
15-20	245	Green mosaic[1]	0	4	5	6	1	—	—	—	6.5
	1934. Plants set June 3										
1-4	390	None	(1g)	(3g)	(1g)	(3g)	—	—	—	—	0.0
5-8	384	Yellow mosaic[1]	3	4(1g)	2	2(2g)	—	—	—	—	2.9
9-12	334	Green mosaic[1]	2	9	5	9	—	—	—	—	7.5
	1935. Plants set June 5										
1-4	358	Yellow mosaic[2]	38	20(1b1g)	14	9	4	4	—	—	24.9
5-8	369	None[3]	(3y)	(6y)	(3y)	(1b)	(1y)	(1y)	—	—	3.9
9-12	341	Mosaic burn stalks[2]	39(1y6g)	44(2y2g)	13	8(5y1g)	4(1y)	1(3y2g)	—	—	31.9
13-16	371	None[3]	(2b1g)	(1b)	(1b)	(1b1y1g)	(1b1y)	(1y1g)	—	—	1.7
17-20	362	Yellow and mosaic burn leaves[4]	71b13y(5g)	38b1y(7g)	14b6y(3g)	18b(2g)	8b	1b7y1g	—	—	41.4
21-24	363	None[3]	2b2y4g	12b7g	1b1y1g	3b1g	3b	1b	—	—	6.0
	1936. Plants set June 1										
1-4	329	Mosaic burn stalks	26	59	22	10	5	0	—	—	37.1
5-7	357	None	0	0	0	0	0	0	—	—	0.0
8-11	328	Mosaic burn leaves	6	10	6	3	2	1	—	—	8.5

1 Stalks chopped into pieces of an inch or more. 2 Stalks and leaves ground in a hammer mill, in 1935 and subsequently. 3 Wind was blowing when the finely ground material was being applied to the "infection" plots. 4 Mixed by accident.

Table 14. (Continued)

Rows	Number of plants set	Kind of virus in added material	Number and kind of mosaic plants found in each inspection							Percent of mosaic plants attributable to added material
			1st	2nd	3rd	4th	5th	6th	7th	8th	
12-14	248	None	0	(1b)	(1b)	(1b)	0	0	—	—	1.2
15-18	337	Yellow mosaic stalks	16	14	8	2	2	1	—	—	12.5
19-21	252	None	0	(3y)	0	0	(1y)	(1y)	—	—	2.0
22-25	331	Yellow mosaic leaves	13	18	6	2	4	0	—	—	13.0
26-28	252	None	(1y)	(1y)	0	0	0	0	—	—	0.8
		1937. Plants set June 7[5]									
1-4	285	Mosaic burn stalks	89	16	15	10	9	0	7	3	52.3
5-7	238	None	(26b1y)	(6b)	(1b)	(4b)	0	(2b)	0	(2g)	16.8
8-11	294	Mosaic burn leaves	103(3y)	41	22	7	10	3	5	4	67.3
12-14	212	None	(3y1g)	(1b2g)	(2b1g)	(2b1y)	(1b)	0	0	(3g)	6.6
15-18	302	Yellow mosaic stalks	64	25	11	0	5	4(1g)	1(1g)	2(1g)	37.1
19-21	215	None	(4y)	(2y)	0	0	0	0	0	0	2.8
22-25	303	Yellow mosaic leaves	56	11	10	6	10	0	0	0	30.7
26-28	220	None	(2g)	(1b3g)	(1g)	—	0	0	0	0	3.2
29-32	231	Green mosaic stalks	25	4	16	7	0	1	2	2	24.7
33-35	210	None	(2g)	(5g)	(3g)	(1g)	0	0	0	0	5.2
36-39	245	Green mosaic leaves	53	39	25	7	6	1	1	6	56.3
40-42	223	None	0	(2g)	(1g)	(1g)	0	(1g)	0	0	2.2

5 The tobacco was set by hand, the crew of 4 men working from row 42 to row 1. This and a heavy rain before setting with wash toward the higher numbered rows probably accounts for most of the mosaic in the rows to which nothing was added as the mosaic material was added when the air was still. The plants grew very slowly after setting, and many mosaic plants which first showed symptoms as much as 6 weeks after setting were believed to have been infected at setting time.

SUMMARY

1. Tobacco mosaic can be controlled by practices designed to prevent initial infection in the plant bed and field. When complete success is not attained in the prevention of field infection, roguing the few mosaic plants which occur, before cultivation, prevents field spread.

2. The most common source of plant-bed and field infection appears to be the workers' hands which have become contaminated from handling viruliferous tobacco used for smoking or chewing. Air-cured and fire-cured tobaccos from infected crops are highly viruliferous.

3. In general the manufactured tobaccos appear to be free from virus or to have a very low virus concentration or for other reasons appear relatively safe for use when setting tobacco. Unless they are virus-free they are probably not safe to use while weeding.

4. Mosaic control appears to be beyond the experimental stage and is being put into successful practice by farmers in Kentucky and other southeastern tobacco-growing states.

5. Infected perennial solanaceous weeds growing on farms where tobacco has been grown frequently may constitute a reservoir of mosaic. This source cannot be disregarded in future studies on initial mosaic infection altho there is now only circumstantial evidence that occasional plants become infected from this source.

6. Insects such as aphids and possibly some other sucking and biting insects may play a part in initial mosaic infection in the field but infection from this source, if it occurs, is minor.

7. While much emphasis has been placed on contaminated soil as a source of initial infection, there is little evidence favoring it. In the south, where roots of plants live thru the winter and mosaic suckers are produced, they can undoubtedly cause infection of an occasional plant. Farther north where plants are killed during the winter there is evidence of very slight infection from virus overwintering in the soil. Where this source of infection has been adequately studied, roguing has been found to be a simple and successful means of preventing injury to the crop if all other sources of infection have been eliminated.

8. Where viruliferous tobacco trash is applied to the land short-

ly before setting, heavy infection may result even tho the infected plants are rogued as soon as mosaic develops.

9. Tobacco mosaic may be controlled satisfactorily under farm conditions by: 1, keeping all tobacco trash of the previous year's crop away from the plant bed and the field; 2, having the hands and pockets of the workers free from tobacco which carries the virus; that is, have them wear clean clothes, or brush all crumbs from their pockets, and wash their hands thoroly with soap and water before handling plants in the plant bed, while setting, and after the plants are in the field; 3, removing from the field all plants which develop mosaic during the summer, preferably before cultivating the crop, and not handling any other plants until the hands have been thoroly washed.

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MILK MARKETING IN LEXINGTON

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Milk Marketing In Lexington

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THE LEXINGTON MILK MARKET

Lexington is primarily a residential city, the wholesale and retail center for a rich agricultural section known as the Central Bluegrass region. According to the 1930 census, the incorporated city had a population of 45,736; the immediately adjacent unincorporated suburbs a population of approximately 12,756;[2] and the universities and colleges a non-resident enrollment of 3,782 students.[3] The potential number of consumers thus is about 62,000 people.

About 28 percent of the city population and nearly a fourth of the population of the market area are negroes. The presence of this considerable number of negroes presents a special problem to the dairy industry, because of their low purchasing power and their habits of consumption.

Many problems encountered in the Lexington market are basically different from those found in larger metropolitan centers. The milk supply is produced near the market and there is little competition from other milk markets. The agencies handling milk are farmers and small distributors. Competition between them introduces certain problems with regard to supply, distribution and price which are of particular significance in a general-farming region where dairying must compete with other farm enterprises.

All milk sold in Lexington is under the supervision of the City Board of Health and must meet the requirements of a city

[1]Acknowledgement is made of the valuable assistance of C. D. Phillips of the Department of Markets and Rural Finance in directing the study in its early stages and advising with the analysis of various milk marketing problems; Professor Fordyce Ely and members of the Dairy Section of the Agricultural Experiment Station, and F. T. Flynn, Market Administrator of the Lexington Area, gave many helpful suggestions during the course of the investigation; Dr. C. M. Moore of the Lexington Department of Health and dealers and dairymen too numerous to mention were helpful in furnishing many data that made the study possible.

[2]Estimated from rural non-farm population.

[3]Estimated from reports from registrars' offices at various institutions in 1935.

milk ordinance. This ordinance establishes minimum standards that necessitate some special equipment on all farms selling milk. However, dairying is not the major source of income on many farms supplying milk for Lexington; consequently many farmers tend to shift in and out of milk production depending upon its profitableness as compared with other enterprises. This tendency is most marked among plant-shippers[1] but it is also applicable to producer-distributors. As a result, the producers' response to price of other products may cause either shortage or surpluses, depending upon whether the dairy enterprise is expanding or contracting.

There is a network of hard surfaced highways leading to Lexington, and the proximity of producers to their market has encouraged farmer delivery. All producers who sell milk at retail and more than half of those who sell to plants deliver their own milk by various means of conveyance; the remainder deliver thru commercial trucking firms. This practice of direct delivery is relatively simple and minimizes the problem of getting milk to market in good condition, but it fosters duplication of service. The proximity of producers to their market has also expedited the growth of distinctive agencies in milk distribution.

Milk is sold by "producer-distributors" who sell raw milk and produce practically all of it; by "plant distributors" who buy all their milk from farmers; and by large producers whose procurement problems are essentially those of producers and whose problems of distribution have many of the characteristics of plant-distributors. This integrated type of distributor is a relatively recent development, the outgrowth of a combination of large size herd and improved small capacity pasteurizers. These dairymen are called "producer-pasteurizers". In so far as these agencies are associated with the management of one or more herds of cattle, they are producers; but because they buy and sell cows to maintain uniform production and also buy considerable quantities of milk, they differ from a typical producer-distributor. They also main-

[1]A plant-shipper is a farmer who sells milk to a milk-marketing concern that operates a milk plant. The concern may be a plant-distributor or a producer-pasteurizer.

tain pasteurizing plants and handle considerable amounts of buttermilk and other dairy products. Thus from a marketing standpoint the nature of their business tends to place them in a class with plant-distributors.

All distributors strive to adjust supply to demand. However, each type of agency handles the problem in a somewhat different manner. Producer-pasteurizers buy and sell cows or buy milk when needed. Producer-distributors expand and contract sales. The plant-distributors increase or decrease the amount of milk diverted to surplus uses. Individual agencies may use any or all of these methods as well as price changes to expedite adjustments to market requirements as the need arises. All things considered, producer-pasteurizers have been the most successful in making the adjustments. Plant-distributors have been the least successful.

DEVELOPMENT OF THE MARKET

Until about 1919, milk was distributed only by farmers who sold raw milk. Since then, pasteurization has been introduced and producer-pasteurizers and plant-distributors have become important.[1] The number of agencies selling pasteurized milk has varied from one to nine, while the number of distributors of raw milk has varied from 40 to 70.

The interest of distributing agencies in developing an organized market has been intermittent. The first major effort to perfect a cooperative association was in 1922. At that time about 40 producer-distributors formed an association to promote the interest of dairy farmers. The association was active in 1926, 1927 and 1928 when compulsory pasteurization of milk was proposed and it was influential in preventing the passage of such an ordinance. Again in 1930, the association was instrumental in formulating plans to handle a feed shortage that was created by severe drouth and in protecting the interest of dairymen during a short period of compulsory pasteurization that was enforced by the City Council. It was also an active agency in promoting the interest

[1]In subsequent discussions all milk which is pasteurized and all dealers selling pasteurized milk are classed together whether they are producers or not.

of its members under the Federal license granted the market by the Agricultural Adjustment Administration in 1934 and 1935.

The first association of producers selling to pasteurizing plants was organized in October, 1933. At that time, the Lexington Graded Milk Producers' Association was incorporated under the Bingham Cooperative Marketing Act. This organization functioned as a bargaining association and was instrumental in obtaining a Federal license for the market. It was active for the period of the license from May, 1934, to April, 1935, and ceased to function when the license was revoked.

Dairymen have thus been unable to develop a strong cooperative milk-marketing system. No basis for market-wide cooperation has been discovered that is generally acceptable to all producing interests and particularly none that will satisfactorily deal with the diverse marketing problems of producer-distributors and dairymen selling milk to plant-distributors. The plant-distributors have likewise made little progress in handling mutual problems cooperatively and except for the period of the Federal license, no formal cooperation can be said to have existed.

THE SOURCE OF MARKET MILK

Except for farms specializing in horse production, general farming is practiced thruout the region. Tobacco is the principal cash crop altho it occupies only about six percent of the area in farms. Other sources of income are livestock, livestock products, corn, wheat, hay and bluegrass seed.

Nearly two-thirds of the area is in pasture. This is nearly three times the combined area of tobacco, corn and hay. Because there is a high percentage of pasture and a scarcity of feed grain, the tendency has been to develop livestock enterprises which utilize pastures and rough feeds. Thus sheep, beef cattle and dairy enterprises are fairly well developed.

The area which supplies milk to Lexington is relatively small. Its outer limits are about 35 miles from town.[1] In 1935, more than 85 percent of the producer-distributors were less than eight

[1]A small amount of milk is received from beyond this distance.

miles from the city and all of them were within 16 miles. Of the farmers selling to milk plants, 40 percent were less than eight miles out and three-fourths of them were not more than 16 miles away.

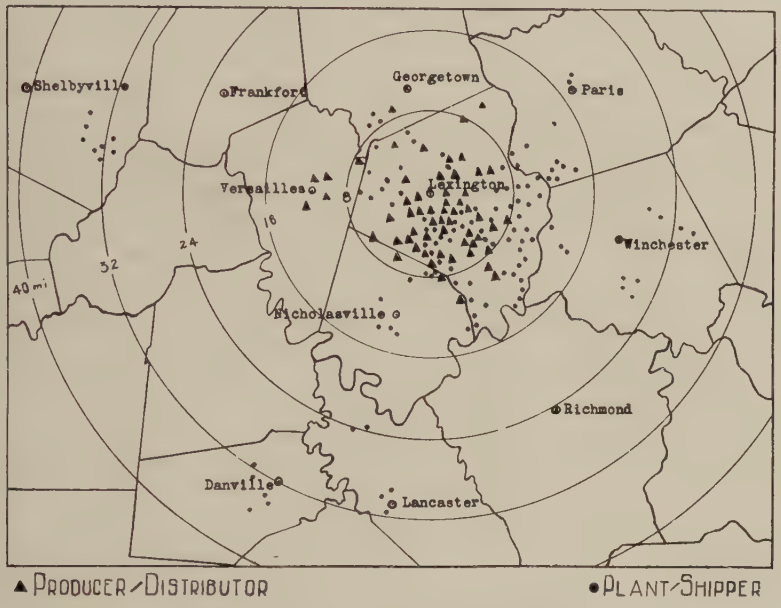

FIGURE 1. Map of the Lexington milkshed.

The average number of cows in the herds of producer-distributors in 1935 was about 25 or four cows larger than the average of plant-shippers. The size of herd of plant-shippers located within the eight-mile zone is comparable to that of producer-distributors but the average size of herd in the eight to 24-mile zone is smaller. The average size of herd beyond the 24-mile zone is about the same as that of producer-distributors in the eight-mile zone.

Producers within the eight-mile zone are engaged in rather intensive agriculture on relatively high-priced land; consequently, milk production is more highly specialized and farmers are less inclined to shift to other enterprises to meet changing economic

conditions than those located at a greater distance from the market. As a general rule, farmers located beyond the eight-mile zone practice more extensive farming than those close in, and other enterprises tend to compete with dairying as a major source of income. When getting milk from a greater distance than 24 miles, milk plants select the larger producers; hence the table shows a larger average size for the herds beyond the 24-mile zone than for those in the intermediate zones.

Table 1. Location of producer-distributors and plant-shippers, 1935.

	Producer-distributors			Plant-shippers[1]			All producers			
Distance from town (miles)	No. of producers	No. of cows	Ave. size herd	No. of producers	No. of cows	Ave. size herd	No. of producers	No. of cows	Ave. size herd	Per-cent of all cows
8 or less	48	1,160	24	40	990	25	88	2,150	24	61.0
8 - 16	9	250	28	39	610	16	48	860	18	24.4
16 - 24				7	119	17	7	119	17	3.4
24 or more				17	395	23	17	395	23	11.2
Total	57	1,410	25	103	2,114	21	160	3,524	22	100.0

[1]Includes producer-pasteurizers.

The proximity of producers to market and the choice of alternative enterprises are factors affecting market stability. Plant distributors receive milk regularly from a selected group of nearby specialized dairies, and they depend upon general farms in outlying areas for additional supplies. Under normal conditions, the summer production of the regular shippers furnishes more milk than is needed on the market; but the plants buy this surplus in order to avoid a shortage of city-inspected milk during the winter. Farmers in the outer zones consequently have a profound effect upon the market because of the influence of other farm enterprises on dairying. Better prices for tobacco, beef cattle, lambs and other products easily discourage milk production on these farms with consequent loss of milk to pasteurizing plants. Higher prices for milk then become necessary if pasteurizing-plants wish to maintain their share of the retail trade in competition with nearby

dairies that distribute their own products. Furthermore, the experience of milk plants in getting much needed supplies during the severe drouth of 1936 demonstrated that farmers are reluctant to produce milk as long as income from other sources is satisfactory.

In general, the producer-distributors stay in the market more consistently than do plant-shippers. Of 77 different producer-distributors who sold milk in Lexington at some time during the six years, 1931-1936, 43, or 56 percent, sold continuously during the entire period. During the same period, there were 184 plant-shippers of whom 75, or 41 percent, sold milk during the entire period. (Table 2.)

Table 2. Distribution of dairymen according to the number of years in which they sold milk during the period, 1931-1936.

	Producer-distributors		Plant-shippers[1]		All shippers	
Number of years	Number of dairies	Percent of dairies	Number of dairies	Percent of dairies	Number of dairies	Percent of dairies
1	8	10.4	22	12.0	30	11.5
2	6	7.8	18	9.8	24	9.2
3	10	13.0	22	11.9	32	12.3
4	5	6.5	38	20.6	43	16.4
5	5	6.5	9	4.9	14	5.4
6	43	55.8	75	40.8	118	45.2
Total	77	100.0	184	100.0	261	100.0

[1]Includes producer-pasteurizers.

The greater continuity of production of producer-distributors is also indicated by the greater stability in number of producers and the size of herds. Table 3 shows that there were some year-to-year changes in the number of these producers during the period of 1931 to 1936, but the number was the same in 1931 as in 1936. Of plant-shippers, on the other hand, there were similar but relatively greater changes in numbers and a net reduction in number of shippers. Likewise, there was a reduction of about four percent

in the size of herds of producer-distributors for the period, as compared with an increase of 15 percent in the size of herds of plant-shippers.

Table 3. Number of dairies and milk cows, 1931-1936.[1]

	Producer-distributors			Plant-shippers[2]			All producers		
During year of	Dairies	No. of cows	Ave. size herd	Pro-ducers	No. of cows	Ave. size herd	Pro-ducers	No. of cows	Ave. size herd
1931	52	1,270	24	125	2,191	18	177	3,461	20
1933	62	1,445	23	151	2,703	18	213	4,148	20
1935	57	1,410	25	103	2,114	20	160	3,524	22
1936	52	1,207	23	117	2,356	20	169	3,563	21

[1]Figures for 1932 and 1934 not available. [2]Includes producer-pasteurizers.

It will be noted that in 1933, when the price of tobacco, the principal cash crop, was low, both the number of producers and the number of cows were high.

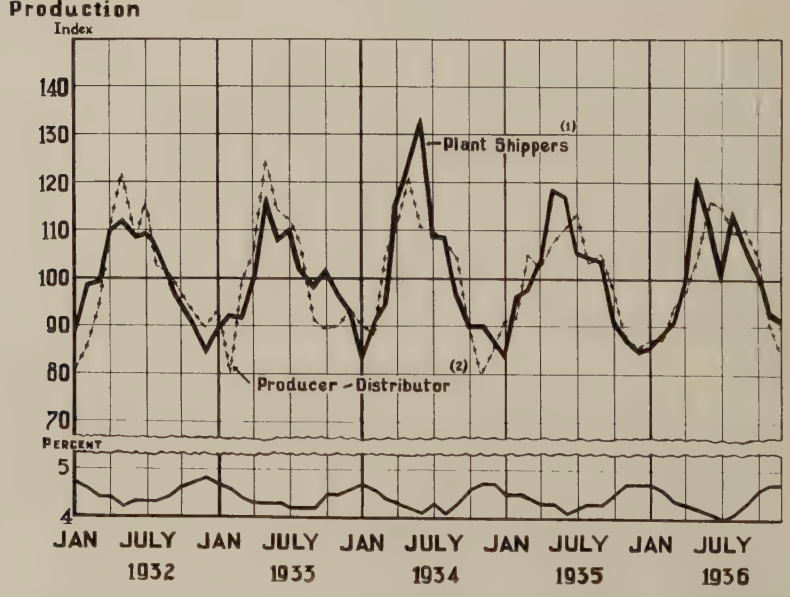

FIGURE 2. Monthly variation in milk supplies and monthly butterfat tests, 1932-1936. Each month adjusted for a 30-day month and expressed in percent of the monthly average for the year. (1) As indicated by plant receipts. (2) From records of herd improvement associations, et al.

Milk production conforms to a seasonal pattern. November to February is a period of low production and April to June a period of flush production. The seasonal trends are similar for producer-distributors and plant-shippers. (See Figure 2.) The production of producer-distributors became more stable and that of plant-shippers became somewhat more variable during the period, 1932-1936. This situation is explained by the shifting of plant-shippers to the class of producer-distributors in 1932 and 1933 when the price of farm products was low, and the later return of these dairymen to their former practice of selling to milk plants, when farming conditions generally were improved. Furthermore, in 1932 and 1933, when the price of milk was low, the plant shippers were indifferent and either failed to deliver or delivered only a part of their milk to plants. Since that time, the prices have been such as to encourage the delivery of all available milk. There was also some tendency for the seasonal variation in production to become less pronounced as farming conditions improved and as some producer-distributors who sold milk in 1932 and 1933 ceased to be producers of market milk in 1935 and 1936.

Changes in the butterfat test in milk received by pasteurizing plants is closely associated with seasonal production. (See Figure 2.) This fact is not fully understood by many farmers and has been a source of dissatisfaction. They often question the accuracy of the butterfat test, or are dissatisfied with the price.

PRICE MECHANISM

In the absence of an organization of dealers or an active association of producers, the price of milk is determined by the bargaining of individual dairymen with plant-distributors and consumers. The price at any time accordingly depends on the needs of the market, the season of the year, production and the competition for supply. For the most part, milk plants buy at a flat price based on a butterfat test of 4.5 percent, with premiums and discounts for milk of higher or lower test.

The price of milk conforms to the price of butter, except for periods when local supply and demand conditions are unusual. Figure 3 shows the price of 92-score butter at Chicago and the

price of milk received by plant-shippers, and illustrates this relationship. The spread between butter and milk prices, it may

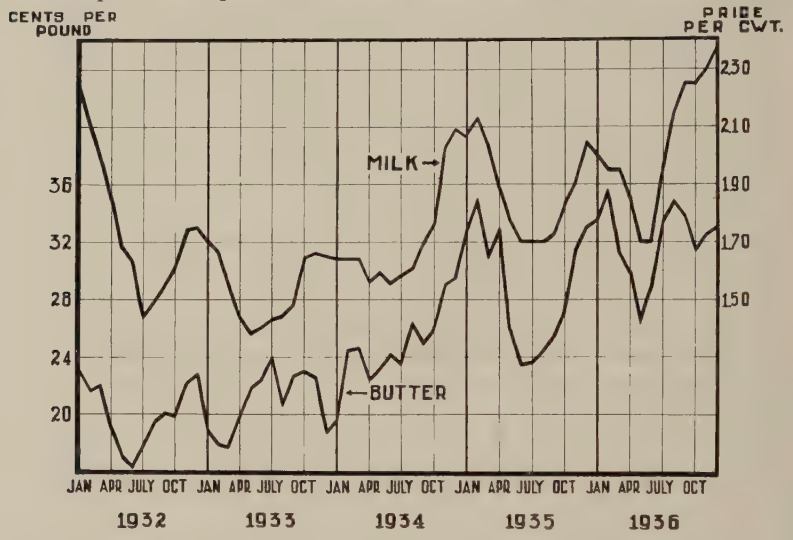

FIGURE 3. Monthly variation in the price of 92-score butter at Chicago and the price of milk, 1932-1936.

be noted, became generally narrower during the period, 1932 to 1936, when butter prices advanced more rapidly than milk prices. Important exceptions to the trend are shown only when the price of butter declined sharply in the winter of 1933-34, and in the summer of 1935, and when the local supply of milk was greatly curtailed by severe local drouth in the fall of 1936. A similar relationship exists between the price of milk and the price of sour cream (see Figure 4) thus indicating the more indirect effect of the price of butter upon the local market for milk. It is significant that the general reduction in the premium paid for market milk has been accompanied by increased receipts, decreased consumption, and larger surpluses of milk.

A further study of Figure 4 shows that the producers of milk received more stable prices than did those selling sour cream. The premium paid for milk during the season of heavy production in certain years was equal to, or greater than, that paid during

the winter months of low production. Such premiums during the periods of flush production appear to have been the result of a policy of distributors to maintain an adequate supply of inspected milk during the seasons of shortage and discourage further producer distribution.

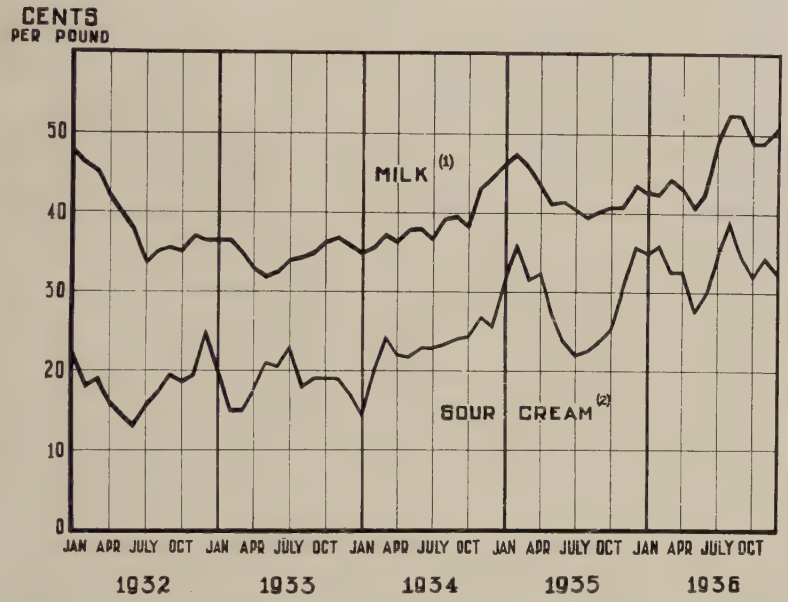

FIGURE 4. Monthly variation in the price received for butterfat in milk bought by milk plants and local price of sour cream, 1932-1936. (1) Based on the average butterfat test and a weighted average price paid by dealers. (2) Weighted average of daily quotations in the Lexington papers.

It may be concluded from the the information at hand, that neither the buying policy of the milk distributors nor the climatic and economic factors of production have been such as to result in uniform milk production. Consequently, there have been periods of seasonally high and low production.

THE CONSUMPTION OF MILK

Complete data on production and sale of milk and milk products for the market as a whole are not available, but the best information indicates that one-third of the milk supply and over one-half of the sales of sweet-milk are in the hands of producer-

distributors. As many producer-distributors have incomplete records of milk sales, an analysis of the use of milk must include some estimates.[1] Since there is a wide variation in the supply of milk and consumer demand is relatively constant, changes in consumption become most significant when considered in relation to production.

From 1932-1936 there was a gradual decline in the amount of whole milk sold by distributors and a gradual increase in market supply. Most of these changes have come since 1933 and during a period of advancing prices. In 1933, sales of whole milk were 10.9 million pounds as compared with 9.4 million in 1936. (See Table 4.) During this period the amount of milk used for cream increased from 2.2 million to 2.9 million pounds.

Table 4. Estimated production and use of milk and cream, 1932-1936.

Year	Estimated production	Sale of market milk	Sale of milk used for cream	Sold as whole milk	Sold as cream
	million lbs.	million lbs.	million lbs.	percent	percent
1932	17.2	10.5	2.2	61	13
1933	16.0	10.9	2.2	67	13
1934	18.0	10.3	2.7	57	15
1935	18.5	9.8	2.5	53	14
1936	17.0	9.4	2.9	55	17

Milk consumption is surprisingly low. The average daily per capita consumption for 1932-1936 was .447 pint. When buttermilk was included the figure was about 25 percent larger, or .561 pint. (See Table 5.) Total consumption of milk, cream, and buttermilk appears to have declined since 1933, as may be noted in Table 5, the decline being from .593 pint in 1933 to .540 pint in 1936. In calculating the annual per capita consumption, no allowance could be made for changes in population during the period. If the apparent observed increase in population could have been used, the decline in consumption would have been even larger.

[1]Records on use represented 70-75 percent of the pasteurized milk and about 10 percent of the raw milk supply. Data for 1934, however, represented 65 percent of the raw-milk business and were used as a check on data for other years.

Factors other than population must therefore be sought to explain the change. A large part, if not all of it, appears to have been due to higher retail prices for milk without corresponding increases in income of consumers.

Table 5. Daily per capita consumption of milk, cream and buttermilk, 1932-1936.[1]

Year	Whole milk	Cream[2]	Buttermilk	Total milk[3]	Average for the United States
	pints	pints	pints	pints	pints
1932	.463	.080	.113	.576	.876
1933	.482	.092	.111	.593	.853
1934	.430	.115	.123	.553	.828
1935	.434	.107	.112	.546	.849
1936	.425	.120	.110	.540	
Ave.	.447	.103	.114	.562	.851[5]

[1]The per capita consumption was computed by dividing the amount of each product sold by a stationary population figure of 62,474. [2]Milk required to supply single and double cream. [3]Total milk is the amount of milk required to furnish whole milk, cream and buttermilk. The uses of milk for cream and buttermilk overlap so that total milk is not the sum of whole milk, cream and buttermilk. [4]Agricultural Statistics, 1936, U. S. D. A. and the Dairy Situation, February, 1937, U. S. D. A. Calculated from gallons. [5]1932-1935 average.

Per capita consumption is low as compared with that of many other urban centers.[1] It is far below the recommended normal requirements for health[2] and considerably below the average consumption for the United States. The combined per capita consumption of sweet milk and buttermilk is about the same as the average in a group of cities reported by the United States Department of Agriculture for the South Atlantic States. The per capita consumption of sweet milk alone exceeded that shown for Baltimore, Md.; Richmond, Va.; Winston Salem, N. C., and Charleston, S. C.; but was exceeded by all the other southern cities reported.[3]

[1]Studies have shown the per capita consumption of milk to be 1.6 pints for Boston (1932), 1.05 pints for Minneapolis (1934), and .83 pint for the United States as a whole (1934). See University of Illinois, Agricultural Experiment Station Bulletin 397, Bartlett, R. W., Prices and Consumption of Milk in Specific Cities; University of Minnesota, Agricultural Experiment Station Bulletin 311, Waite, Warren C. and Cox, Rex, A Study of the Consumption of Dairy Products in Minnesota, 1934, and U. S. D. A., Agricultural Statistics, 1937, page 301.

[2]One pint daily for adults, and one quart for children, is a recommendation of the Bureau of Home Economics, U. S. D. A., and the National Dairy Council.

[3]Consumers Council Division, AAA, U. S. D. A., Consumers Council Series Pub. No. 2, A Survey of Milk Consumption in 59 Cities of the United States, June, 1936.

SURPLUS AND SHORTAGE

Milk in excess of that required for whole milk and cream is considered as surplus in this analysis. A shortage is considered to exist only when there is not a sufficient supply to satisfy these uses. Annual surpluses for the period studied were 26.2 percent for 1932, 19.7 percent for 1933, 27.7 percent for 1934, 33.2 percent for 1935 and 30.2 percent for 1936. Seasonal surpluses vary more widely and are more significant. For example, the annual surplus for 1932 was 26.2 percent, but monthly surpluses ranged from 3.2 percent in January to 42.2 percent in July. Table 6 shows that

Table 6. Estimated production and sale of milk and cream, 1932-1936.[1]

Year	Estimated production of producer-distributors plus plant receipts	Whole Milk		Cream		Milk sold as whole milk and cream, in percent of production
		Sales	Percent of production	Milk separated and sold as cream	Percent of production	
1932	pounds	pounds		pounds		pounds
Jan.	1,220,905	953,807	78.1	228,721	18.7	96.8
Feb.	1,304,858	904,352	69.3	190,078	14.6	83.9
Mar.	1,393,226	845,866	60.7	197,234	14.2	74.9
Apr.	1,557,048	938,175	60.3	211,530	13.6	73.9
May	1,669,351	896,445	53.7	191,040	11.4	65.1
June	1,568,522	851,070	54.3	149,900	9.6	63.9
July	1,622,544	802,300	49.4	136,474	8.4	57.8
Aug.	1,541,351	800,783	52.0	125,531	8.1	60.1
Sept.	1,431,365	852,820	59.6	147,607	10.3	69.9
Oct.	1,384,764	881,172	63.6	195,760	14.1	77.7
Nov.	1,277,558	889,010	69.6	191,944	15.0	84.6
Dec.	1,213,134	918,727	75.7	185,608	15.3	91.0
Total	17,184,626	10,534,527	61.3	2,151,427	12.5	73.8
1933						
Jan.	1,217,192	936,970	79.2	184,308	15.1	94.3
Feb.	1,150,939	946,764	82.3	169,688	14.7	97.0
Mar.	1,265,137	928,007	73.4	170,466	13.5	86.9
Apr.	1,378,575	868,631	63.0	159,184	11.5	74.5
May	1,658,151	906,515	54.7	194,690	11.7	66.4
June	1,504,858	895,119	59.5	172,427	11.5	71.0
July	1,536,569	886,574	57.7	169,445	11.0	68.7
Aug.	1,465,537	826,708	56.4	159,107	10.9	67.3
Sept.	1,326,321	905,953	68.3	183,875	13.9	82.2
Oct.	1,343,311	918,974	68.4	198,194	14.8	83.2
Nov.	1,246,316	946,688	76.0	197,100	15.8	91.8
Dec.	1,240,159	942,907	76.0	217,348	17.5	93.5
Total	16,333,065	10,936,810	67.0	2,175,832	13.3	80.3

[1]Adjusted for a 30 day month.

Tabe 6. (Continued)

Year	Estimated production of producer-distributors plus plant receipts	Whole Milk		Cream		Milk sold as whole milk and cream, in percent of production
		Sales	Percent of production	Milk separated and sold as cream	Percent of production	
1934	pounds	pounds		pounds		pounds
Jan.	1,261,559	867,555	68.8	176,236	14.0	82.8
Feb.	1,248,469	888,641	71.2	234,416	18.8	90.0
Mar.	1,429,869	879,154	61.5	263,431	18.4	79.9
Apr.	1,672,994	881,785	52.7	259,521	15 5	68.2
May	1,862,953	869,801	46.7	257,092	13.8	60.5
June	1,699,939	826,790	48.6	219,672	12.9	61.5
July	1,671,077	826,096	49.4	213,101	12.8	62.2
Aug.	1,690,613	783,245	46.3	187,542	11.1	57.4
Sept.	1,486,393	903,509	60.8	228,670	15.4	76.2
Oct.	1,392,955	895,955	64.3	237,750	17.1	81.4
Nov.	1,302,849	841,375	64.6	215,805	16.6	81.2
Dec.	1,289,673	810,808	62.9	240,696	18.7	81.6
Total	18,009,343	10,274,714	57.1	2,733,932	15.2	72.3
1935						
Jan.	1,336,752	875,066	65.5	214,842	16.1	81.6
Feb.	1,321,594	886,290	67.1	204,145	15.4	82.5
Mar.	1,489,018	853,473	57.3	220,596	14.8	72.1
Apr.	1,541,217	835,459	54.2	203,113	13.2	67.4
May	1,784,996	791,734	44.4	199,966	11.2	55.6
June	1,752,245	789,465	45.1	200,322	11.4	56.5
July	1,689,699	778,148	46.1	197.042	11.7	57.8
Aug.	1,637,123	756,514	46.2	184,551	11.3	57.5
Sept.	1,573,987	824,371	52.4	206,529	13.1	65.5
Oct.	1,415,546	856,117	60.5	225,408	15.9	76.4
Nov.	1,292,501	816,805	63.2	230,596	17.8	81.0
Dec.	1,268,020	781,416	61.6	257,819	20.3	81.9
Total	18,102,698	9,844,858	54.4	2,544,929	14.1	66.8
1936						
Jan.	1,237,418	786,864	63.6	263,087	21.3	84.9
Feb.	1,206,730	795,628	65.9	238,947	19.8	85.7
Mar.	1,321,860	804,721	60.9	260,469	19.7	80.6
Apr.	1,384,125	785,717	56.8	250,780	18.1	74.9
May	1,653,172	778,153	47.1	274,807	16.6	63.7
June	1,576,421	750,658	47.6	233,081	14.8	62.4
July	1,499,046	719,715	48.0	200,901	13.4	61.4
Aug.	1,611,647	703,425	43.6	175,457	10.9	54.5
Sept.	1,510,800	748,602	51.9	205,939	13.6	65.5
Oct.	1,468,725	822,534	56.0	255,866	17.4	73.4
Nov.	1,286,814	815,984	63.4	228,276	17.7	81.1
Dec.	1,278,000	808,659	63.3	272,922	21.4	84.7
Total	17,034,758	9,356,660	54.9	2,860,532	16.8	69.8

there were a number of instances in 1932 and 1933 when the supply was barely adequate to meet sales of whole milk and cream. Such a close margin for the month indicates that there were some days during the month when scarcely enough milk was received to meet the current demand for milk and cream and no milk was available for manufactured products. At times, it has been difficult, if not impossible, to get needed supplies of fluid milk, and dealers have resorted to the purchase of cream, cottage cheese and other products from outside the area. Prior to 1934 the possibility of a milk shortage was a real threat at times, but since then the problem has been chiefly one of equalization of supplies among distributors.

MARKET COMPETITION

Stability of milk production is not peculiar to the Lexington market but it is one of the major problems. On the whole, the business concerns operating pasteurizing plants are in a better position to handle surplus and to obtain adequate supplies during seasons of low production than are producer-distributors but since there is not an equable distribution of supplies, some of the distributing agencies are either short of milk and find difficulty in getting additional supplies or have a surplus and inadequate facilities for handling it. This situation exists in all phases of competition within the market but can best be shown in a study of the changes in the sales of milk by producer-distributors and dealers selling pasteurized milk.

Figure 5 shows the extent and nature of the variation in sales by producer-distributors and pasteurizing plants, expressed on a monthly index basis, for the period, 1932-1935. The average range of milk sales for pasteurizing-plants was from 89 to 111 and for producer-distributors it was from 92 to 104.[1] Pasteurizing plants appear to experience wider variations in milk sales because they have a large percentage of the wholesale trade which is more variable than the retail trade.

Seasonal changes in relative importance of these two types of

[1]Milk for manufacturing is excluded.

milk distributors reflect changes in production and prices and their consequent influence on consumer buying habits.

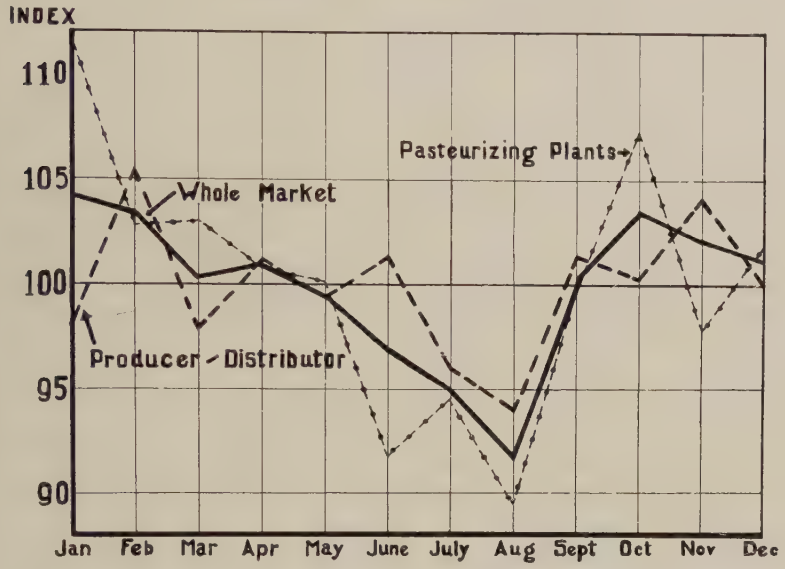

FIGURE 5. Monthly variation in milk sales by pasteuring plants, producer-distributors, and combined sales of pasteurizing plants and producer-distributors. Data adjusted for trend and 30-day month. Monthly averages are expressed in percent of the 1932-1935 monthly average. Milk for manufacturing is excluded.

When individual months are considered, the interchange in business between producer-distributors and other agencies appears rather definite. Figure 5 shows, for example, that there is a shift from distributors handling pasteurized milk to producer-distributors in February. At this time of year milk production is increasing and some producer-distributors make price concessions in order to recover business lost in December and January. By late February or early March, some of them have sold more milk than they can deliver, and the milk plants have adjusted price to meet competition so that again there is a shift in sales, plant sales increase and a new relationship is established that continues thru April and May. By June, sales of raw milk have stepped up again and producer-distributors hold this advantage until late summer. Beginning in September, distributors selling pasteurized milk again have

larger sales, and they continue to gain on producer-distributors until late in October or early November, when they generally advance retail milk prices because of small supplies of milk. Sales then drop sharply and customers appear to turn to producer-distributors who have not advanced prices. By December, the producer-distributors are beginning to run short of milk and raise prices or cut off some of their customers and as a result milk plants again get part of the business of producer-distributors and continue to increase their sales thru January. Consumers are decidedly sensitive to price changes from the standpoint of source of milk supply and they shift rather readily from one source of supply to another on the basis of price. The seasonal demand for milk for the market as a whole, however, follows the rather definite seasonal pattern shown by combined sales of all pasteurizing plants and producer-distributors in Figure 5.

There are also seasonal fluctuations in cream sales but sales by pasteurizing plants differ greatly from those of producer-distributors.[1]

Figure 6 shows that the amount of cream sold by producer-distributors is largest in summer and smallest in winter whereas the amount sold by pasteurizing plants is smallest in summer and largest in winter. Sales of cream by producer-distributors are mostly at retail and the amount of cream sold is largely determined by the supply of surplus milk. During flush summer production, surplus milk from their own dairies provides most, if not all, cream required by milk patrons but in winter if they are short of milk, as many of them are, customers are often forced to depend on other sources. On the other hand, cream sales of pasteurizing plants are largely wholesale, their trade is more variable and affected to a greater degree by summer vacation, and hot weather shifts from coffee and heavy cream-containing foods to lighter foods and cooling drinks. Furthermore, the winter sales of pasteurizing plants represent their normal trade plus that of the patrons of producer-distributors who cannot supply cream.

While there has been considerable seasonal interchange in busi-

[1]Cream for manufacturing purposes is not included.

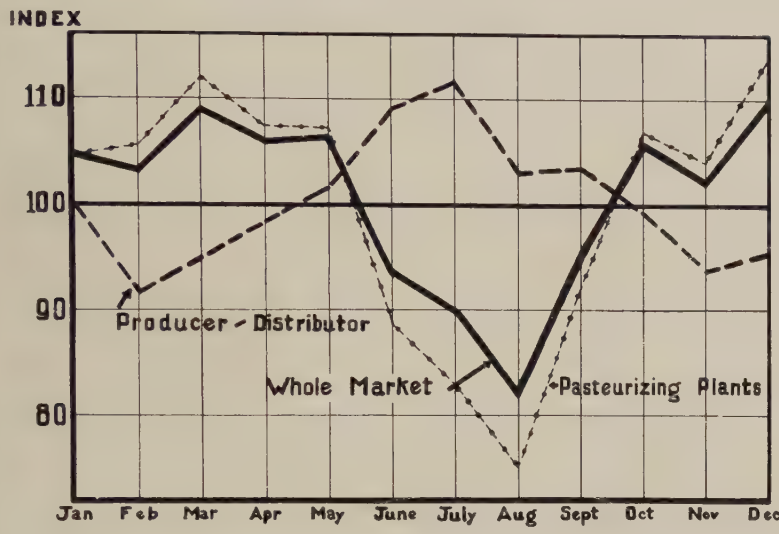

FIGURE 6. Monthly variation in cream sales by pasteurizing plants, producer-distributors and combined sales of pasteurizing-plants and producer-distributors. Data adjusted for trend and 30-day month. Monthly averages are expressed in percent of the 1932-1935 monthly average. Cream for manufacturing is excluded.

ness between pasteurizing plants and producer-distributors, the proportionate share of the total market that each type of distributor handles has been fairly constant from year to year. (See Table 7.) The exception noted in 1935 was the result of intra-market competition of a temporary rather than a basic nature.

Table 7. Percentage of milk and cream handled by pasteurizing plants and producer-distributors annually, 1932-1936.

Year	Milk sales		Cream sales	
	Pasteurizing plants	Producer-distributors	Pasteurizing plants	Producer-distributors
1932	48.4	51.6	74.6	25.4
1933	47.9	52.1	77.0	23.0
1934	47.6	52.4	81.9	18.1
1935	42.2	57.8	78.1	21.9
1936	49.0	51.0	81.9	18.1

Sufficient records were not available upon which to base a definite conclusion in regard to the interchange of sales for other dairy products but some estimates of total sales were possible.

Buttermilk constitutes over 20 percent of the total sales of milk in Lexington. This by-product of cream is sold by some producer-distributors but the amount sold varies widely from time to time and from dairy to dairy. Altho no estimates of the monthly interchange of sales were possible, indications are that pasteurizing plants handled 80 to 85 percent of the total.

The sale of cottage cheese is relatively small. An average of less than five percent of the annual supply of milk is used for this purpose. The demand for cottage cheese is decidedly seasonal and pasteurizing plants furnish the bulk of the supply.

Sales of chocolate milk do not exceed two percent of the annual supply. Its use is confined largely to school trade and here again dealers operating pasteurizing plants furnish almost the entire amount.

Butter is made chiefly as a means of disposing of surplus milk. Since it is bought as well as sold and no records are available, an analysis cannot be given.

AN ANALYSIS OF USE OF MILK BY PASTEURIZING PLANTS

Distributors that operate pasteurizing plants occupy a position somewhat different from that of similar distributors in large milk markets. They sell only about one-half of the bottled milk of the city and distribute a relatively large proportion of manufactured products. They also handle most of the surplus milk. For this reason they act as a buffer in times of shortage, and furnish the bulk of the cream, buttermilk and cottage cheese. They handle about two-thirds of the total milk receipts of the market and receive milk from more than two-thirds of the inspected dairy herds of the area. Consequently, the use of milk by these agencies is significant to all groups interested in milk marketing.

The use made of milk by pasteurizing plants varied widely from plant to plant and from year to year. In the period from 1932 to 1936 the percent of whole milk sold in bottles varied from a low of 36.8 percent of total milk in 1935 to a high of 55.2 percent in 1933. That used for cream varied from a low of 15.0 percent in 1932 to a high of 20.4 percent in 1936. Corresponding figures for buttermilk were 21.1 percent in 1935 and 22.8 percent in 1932;

for cottage cheese 2.8 percent in 1934 and 5.6 in 1936; for chocolate milk 0.4 percent in 1934 and 1.8 in 1933. (See Table 8.)

Milk in excess of requirements for the products considered above was used for manufacture of butter, ice cream, and for other purposes. The monthly surpluses above the whole milk and cream requirements varied from 5.1 percent in January, 1933, to 53.7 percent in June, 1935, and the annual surplus ranged from 18 percent in 1933 to 37.6 percent in 1935. Since 1933 there has not been a shortage of milk to supply the Lexington bottled milk and cream trade, but there may have been instances when individual plants were not in a position to supply all of their demands.

There have also been some distinct trends in the use of milk. (See Figure 7.) Sales of whole milk, especially bottled milk, declined; the amount of milk separated for double cream remained fairly constant while that separated for single cream increased.

Skim-milk made available by separating whole milk was used

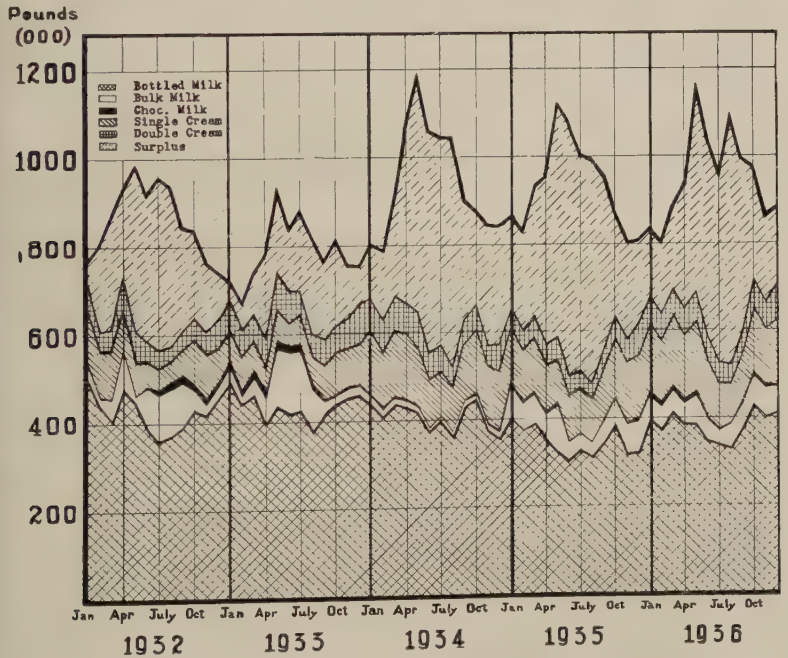

FIGURE 7. Use of milk purchased by pasteurizing plants, 1932-1936.

Table 8. Percent of total milk receipts of pasteurizing plants used as whole milk, cream, buttermilk and cottage cheese.

Year and Month	As whole milk				For cream[2]				Total for cream and as whole milk	Buttermilk					Milk for cottage cheese	Total
	Bottled	Bulk	Chocolate[1]	Total	Bottled: Single	Bottled: Double	Bulk[3]	Total		Bottled	Bulk[3]	Total	Available from cream	Difference[5]		
1932																
Jan.	65.6	4.3	.3	70.2	14.8	8.7	—	23.5	93.5	36.5	—	36.5	23.0	13.5	.3	107.5[6]
Feb.	54.4	2.2	.7	57.3	12.1	5.9	—	18.0	75.3	20.8	—	20.8	18.2	2.6	3.1	81.0
Mar.	46.8	5.6	.8	53.2	12.0	5.4	—	17.4	70.6	18.9	—	18.9	24.0	+5.1	4.1	69.6
Apr.	51.6	9.2	.6	61.4	10.0	7.8	—	17.8	79.2	26.5	—	26.5	19.7	6.8	4.6	90.6
May	45.5	1.5	.4	47.4	7.1	7.5	—	14.6	62.0	25.9	—	25.9	20.9	5.0	3.1	70.1
June	42.4	9.9	.5	52.8	5.9	5.4	—	11.3	64.1	24.8	—	24.8	20.2	4.6	4.3	73.0
July	37.8	10.7[4]	1.6	50.1	4.9	4.7	—	9.6	59.7	20.2	—	20.2	15.6	4.6	3.0	67.3
Aug.	39.5	11.6[4]	2.0	53.1	4.4	4.4	—	8.8	61.9	21.6	—	21.6	15.9	5.7	3.7	71.3
Sept.	46.4	11.8[4]	2.5	60.7	6.6	5.5	—	12.1	72.8	24.1	—	24.1	17.1	7.0	4.9	84.7
Oct.	51.3	5.3	2.1	58.7	11.7	6.3	—	18.0	76.7	19.4	—	19.4	19.9	+ .5	4.6	80.8
Nov.	54.9	3.2	2.0	60.1	12.5	7.0	—	19.5	79.6	20.6	—	20.6	19.4	1.2	3.5	84.3
Dec.	62.4	2.6	1.9	66.9	10.4	8.5	—	18.9	85.8	20.1	—	20.1	18.5	1.6	3.3	90.7
Wt. Ave.	48.2	6.9	1.3	56.4	8.8	6.2	—	15.0	71.4	22.8	—	22.8	19.4	3.4	3.7	78.5
1933																
Jan.	68.5	4.4	2.7	75.6	9.2	10.1	—	19.3	94.9	21.2	—	21.2	17.5	3.7	4.5	103.1[6]
Feb.	66.2	2.6	2.6	71.4	10.5	9.5	—	20.0	91.4	21.2	—	21.2	17.9	3.3	3.9	98.6
Mar.	62.6	5.3	2.5	70.4	8.7	9.0	—	17.7	88.1	21.1	—	21.1	18.2	2.9	6.0	97.0
Apr.	50.8	7.9	2.1	60.8	6.7	8.8	—	15.5	76.3	17.9	—	17.9	19.9	+2.0	6.9	81.2
May	46.7	13.5[4]	2.5	62.7	7.4	9.1	—	16.5	79.2	20.1	—	20.1	24.3	+4.2	6.9	81.9
June	49.9	16.4[4]	2.1	68.4	6.2	8.8	—	15.0	83.4	23.8	—	23.8	24.2	+ .4	6.3	89.3
July	48.3	15.2[4]	2.0	65.5	7.4	6.3	—	13.7	79.2	18.1	—	18.1	18.5	+ .4	3.9	82.7
Aug.	46.5	11.1[4]	1.9	59.5	7.7	6.1	—	13.8	73.3	22.5	—	22.5	21.4	1.1	3.3	77.8
Sept.	55.2	2.9	.8	58.9	10.4	8.0	—	18.4	77.3	25.4	—	25.4	15.6	9.8	1.8	88.9
Oct.	53.9	2.1	.9	56.9	10.9	8.0	—	18.9	75.3	23.2	—	23.2	14.8	8.4	2.7	86.9
Nov.	60.5	2.3	1.0	63.8	11.2	9.7	—	20.9	84.7	27.6	—	27.6	17.9	9.7	2.1	96.5
Dec.	61.4	2.2	.8	64.4	12.2	12.1	—	24.3	88.7	26.2	—	26.2	20.4	5.8	2.0	96.4
Wt. Ave.	55.2	7.3	1.8	64.3	9.0	8.7	—	17.7	82.0	22.5	—	22.5	19.2	3.3	4.3	89.6
1934																
Jan.	54.6	2.2	.5	57.3	11.0	9.3	7.0	27.3	84.6	26.8	4.6	31.4	22.6	8.8	1.8	95.2

[1] Chocolate milk is included in bulk milk for 1932 and 1933.
[2] Cream is reported in terms of 40% cream.
[3] Bulk cream is included in bulk milk for 1932 and 1933.
[4] Bulk milk is included in bottled milk for 1932 and 1933.
[5] Difference between buttermilk available from cream and buttermilk sold.
[6] Total is not equal to the sum of the items because of rounding.

Aug.	39.0	.7	.2	39.7	8.7	4.2	5.1	14.5	45.1	15.1	5.9	21.0	14.9	5.5	2.5	61.7
Sept.	47.8	1.3	.4	49.5	9.2	5.8	5.2	20.2	69.7	19.1	4.9	24.0	16.6	7.4	3.2	80.3
Oct.	50.8	1.5	1.0	53.3	10.3	6.4	5.8	22.5	75.8	20.9	5.3	26.1	18.6	7.5	3.3	86.6
Nov.	44.2	1.6	.9	46.7	8.9	5.6	6.1	20.6	67.3	16.1	4.0	20.1	17.2	2.9	2.5	72.7
Dec.	42.4	1.7	.8	44.9	9.7	7.1	5.9	23.0	67.9	15.2	7.8	23.0	19.0	4.0	2.2	74.1
Wt. Ave.	42.8	1.3	.4	44.5	8.8	6.7	4.8	20.3	64.8	18.4	4.9	23.3	16.8	6.4	2.8	74.0
1935																
Jan.	46.5	8.3	1.2	56.0	8.7	5.4	5.6	19.7	75.7	15.0	7.8	22.8	16.2	6.6	1.7	84.0
Feb.	45.4	7.0	1.1	53.5	7.4	5.9	6.2	19.5	73.0	15.0	9.8	24.8	16.1	8.7	2.1	83.8
Mar.	41.7	7.0	1.0	49.7	6.6	5.7	6.4	18.7	68.4	14.7	8.1	22.8	15.4	7.4	2.3	78.1
Apr.	36.5	6.4	.7	43.6	5.7	4.9	5.5	16.1	59.7	13.9	7.6	21.5	13.3	8.2	2.4	70.3
May	28.9	9.4	.6	38.9	4.7	4.5	4.1	13.3	52.2	11.0	5.5	16.5	11.0	5.5	2.3	60.0
June	28.2	4.0	.3	32.5	5.4	4.2	4.2	13.8	46.3	11.6	4.2	15.8	11.4	4.4	2.6	53.3
July	32.6	3.5	.2	36.3	5.3	3.8	5.2	14.3	50.6	13.6	5.4	19.0	11.8	7.2	3.7	61.5
Aug.	31.5	3.2	.2	35.0	5.9	3.5	4.2	13.6	48.6	13.4	5.0	18.4	11.2	7.2	3.1	58.9
Sept.	36.1	5.2	.7	42.0	7.3	4.5	5.1	16.9	58.9	15.1	7.4	22.5	13.8	8.7	4.2	71.8
Oct.	44.1	6.7	1.0	51.8	9.5	5.3	6.1	20.9	72.7	17.1	8.6	25.7	17.1	8.6	3.9	85.2
Nov.	39.5	8.3	.9	48.7	10.3	6.2	6.9	23.4	72.1	17.3	6.4	23.7	19.1	4.6	3.2	79.9
Dec.	39.8	8.6	1.3	49.7	11.6	9.3	6.1	27.0	76.7	18.1	6.6	24.7	22.4	2.3	4.4	83.4
Wt. Ave.	36.8	7.3	.7	44.8	7.1	5.1	5.4	17.6	62.4	14.4	6.7	21.1	14.5	6.6	3.0	72.0
1936																
Jan.	47.7	6.3	1.4	55.4	10.9	7.8	7.8	26.5	81.9	20.3	7.8	28.1	21.9	6.2	3.7	91.8
Feb.	47.0	6.1	1.6	54.7	10.2	7.2	7.6	25.0	79.7	20.7	9.0	29.7	20.6	9.1	3.9	92.7
Mar.	47.2	5.3	1.4	53.9	10.3	6.8	7.8	24.9	78.8	20.2	6.9	27.1	20.5	6.7	4.9	90.4
Apr.	41.3	4.9	1.4	47.6	8.6	6.8	7.0	22.4	70.0	19.7	6.0	25.7	18.5	7.2	5.4	82.6
May	33.0	5.6	1.0	39.6	6.4	6.2	7.2	19.8	59.4	14.3	1.7	16.0	16.4	+ .4	5.0	64.8
June	33.7	4.5	.6	38.8	6.4	5.6	6.0	18.0	56.8	16.3	1.7	18.0	14.9	3.1	6.9	66.8
July	35.2	3.5	.4	39.1	5.5	5.5	4.9	15.9	55.0	15.9	2.2	18.1	14.9	3.2	7.5	65.7
Aug.	30.0	5.1	.3	35.4	4.5	4.1	3.3	11.9	47.3	12.6	1.0	13.6	9.6	4.0	5.6	56.9
Sept.	37.9	5.5	.7	44.2	5.9	5.1	5.2	16.2	60.4	14.7	1.1	15.8	13.2	2.6	5.9	68.8
Oct.	43.4	7.1	1.1	51.6	7.5	6.6	7.7	21.8	73.4	16.4	2.2	18.6	18.0	.6	6.5	80.5
Nov.	46.5	7.6	1.0	55.1	7.8	7.1	6.8	21.7	76.8	16.6	3.0	19.6	18.0	1.6	6.1	84.5
Dec.	46.5	6.6	.7	53.8	9.3	9.5	7.4	26.2	80.0	17.1	2.7	19.8	21.8	+2.0	5.4	83.4
Wt. Ave.	40.1	5.6	.9	46.6	7.8	6.4	6.2	20.4	67.0	18.4	3.5	21.9	17.4	3.5	5.6	76.1

[1]Low butterfat content. [2]Does not include cream for ice cream or other manufactured products. [3]Bulk or gallon sales could not be estimated in 1932 and 1933. [4]Figures for these months include some bulk milk sold for ice cream. [5]A plus sign (+) indicates excess from cream. [6]Total uses obtained from the plant records showed that more milk was sold than was shown on their receipt sheets. Cream and other dairy products purchased from outside the market caused the apparent excess of sales over receipts.

in manufacturing buttermilk and cottage cheese. The amount of these products sold by milk plants remained about constant during the period of this study. (See Figure 8.) There was also

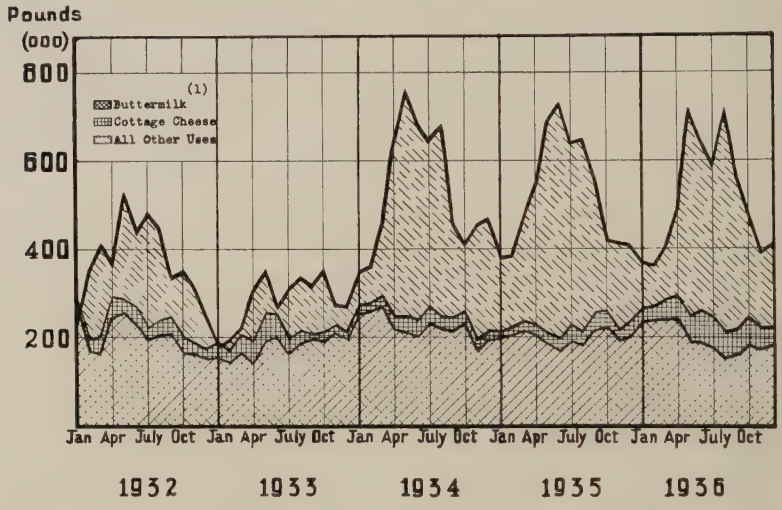

FIGURE 8. Use of surplus by pasteurizing plants, 1932-1936. (1) Skim-milk from which cream has been taken is counted in buttermilk.

a steady increase in receipts of whole milk over and above the various market requirements for whole milk, as may be noted in Figure 8. This development creates a serious problem of management of milk plants and is indirectly of much significance to dairymen since buyers cannot continue to take increasing quantities of whole milk at prevailing prices when an ever larger proportion of it must be diverted to less valuable uses. Occasionally, the milk plants were able to dispose of small quantities of whole milk in the small markets of Eastern Kentucky but the bulk of the surplus has at all times been used for manufacture of butter or other dairy products.

Market price appears to have been an important cause of the growing surplus. Higher prices paid to farmers were accompanied by increasing supplies of milk whereas advancing retail prices were followed by lower consumption. For example, a reduction of 22 cents per hundred weight, or 12.5 percent, in the yearly

average price from 1932 to 1933, was accompanied by a decline of 8.5 percent in plant receipts whereas an accompanying decline of 1.1 cents per quart, or 11.4 percent, in the retail price was attended by an increase in consumption of 3.5 percent. From 1933 to 1936 the price paid dairymen for milk advanced 40 percent and plant receipts increased 20 percent but the increase in retail price of 1.8 cents per quart, or 20 percent, was accompanied by a decline of 12.8 percent in consumption. Thus, during the last three years, the response of dairymen and consumers to changes in milk prices has resulted in larger production, lower consumption and an increase in market surplus. A small surplus is desirable at all times in markets for essential food products but the question may be raised whether it need be as large as during recent years to protect the dietary standard of the local population.

The size and character of the market surplus may be better understood if the character of consumption and supply is further analyzed. For example, the consumption of whole milk was greatest from October to February when production was lowest, and was least from June to August when production was comparatively large. (See Figure 9.) The seasonal variation in consumption of other milk products is also large but in no case do they show as close inverse relation to production as whole milk.

Different factors appear to influence the consumption of the products differently. In the case of milk the changes were closely associated with changes in total population. The tobacco industry attracts a large number of people to the city during the winter, the students have returned, and few people are away on vacation. Conversely, during the summer a considerable number of people are away on vacation, schools are closed and the university student population is much reduced.

In the case of buttermilk, it is believed that employment and price are the major factors. Consumption is greatest in January when employment in the local tobacco industry is highest. The low consumption in November and December comes at a time when the supplies of skim-milk for manufacture are short and the price of buttermilk is normally highest.

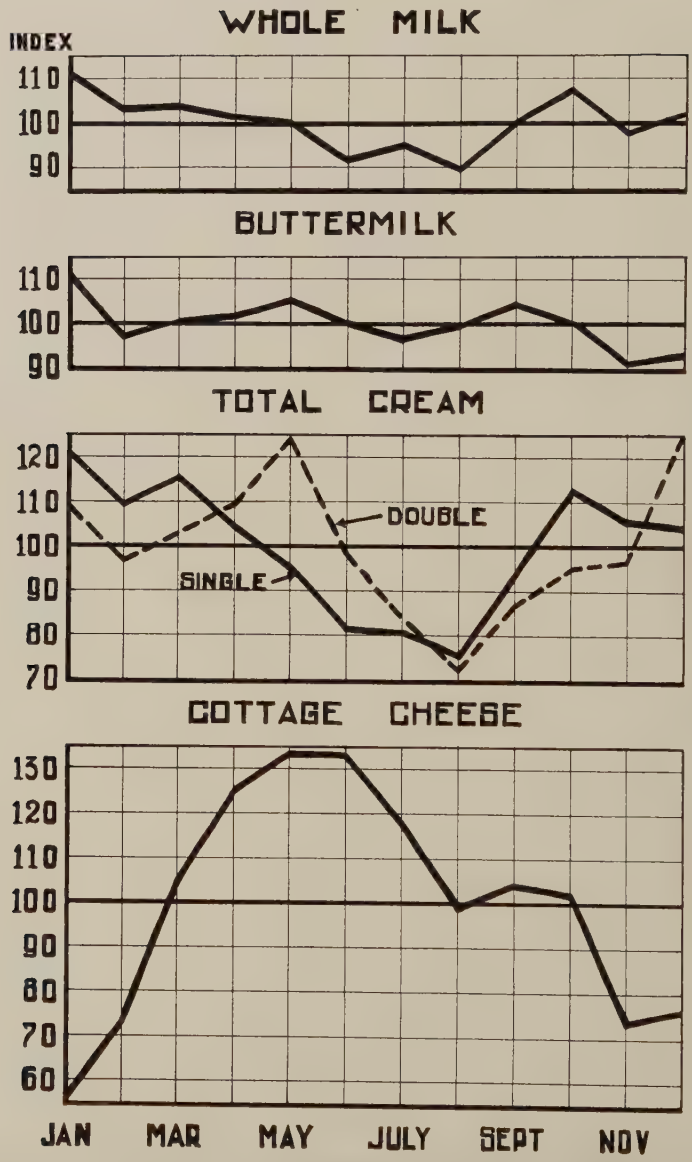

FIGURE 9. Monthly variation in consumption of certain dairy products, 1932-1935, expressed in percent of the 1932-1935 monthly average. Data adjusted for 30-day month and corrected for trend.

The spring peak in consumption of double cream is closely associated with the fresh berry season and the fall peak with holidays. The consumption of single cream is largest thruout the winter, and does not appear to be affected to an important degree by the berry season or holidays. Single cream is used more or less regularly and it appears that total population and other factors affecting the whole milk trade are also important considerations affecting the consumption of this product.

Sales of cottage cheese reach a maximum in May and June as a result of increased use in salads and cold foods. The low point comes in January at a time when milk supplies are shortest and skim-milk can be more profitably utilized in other ways. Thus the consumption of dairy products as a whole is affected by the seasonal change in total population and the shifts of consumers from heavy foods and coffee in winter to lighter food, tea and cooling drinks in summer.

VARIATION IN CONSUMPTION BY DAYS OF THE WEEK

Not only does the consumption of dairy products vary with the season, but it also varies with the day of the week. The habits of the people, the nature of the product, and the system of distribution interact to cause more or less characteristic patterns. The time and extent of daily variations cannot accurately be determined, but a study of the average of these variations is helpful in understanding some of the problems involved.

When only the sweet milk and cream sales by pasteurizing plants were considered, there was less than one percent variation from the weekly average from Monday to Friday. There was an increase of 9.5 percent on Saturday and a decline of 9.1 percent on Sunday. (See Figure 10.)

The daily average of week-end consumption including Monday was about the same as the daily average during the fore part of the week. Thus, the milk and cream market requirements would have been fairly constant if there had been uniform daily distribution over the week. This was not the case, however, and since many stores selling milk and cream close on Sunday, store customers bought their Sunday requirements the preceding day. This

being the case, plants furnished the increased supplies for Saturday and handled the surplus caused by the drop in sales on Sunday. When the milk required to furnish buttermilk and cottage cheese was added to that required for whole milk and cream, the

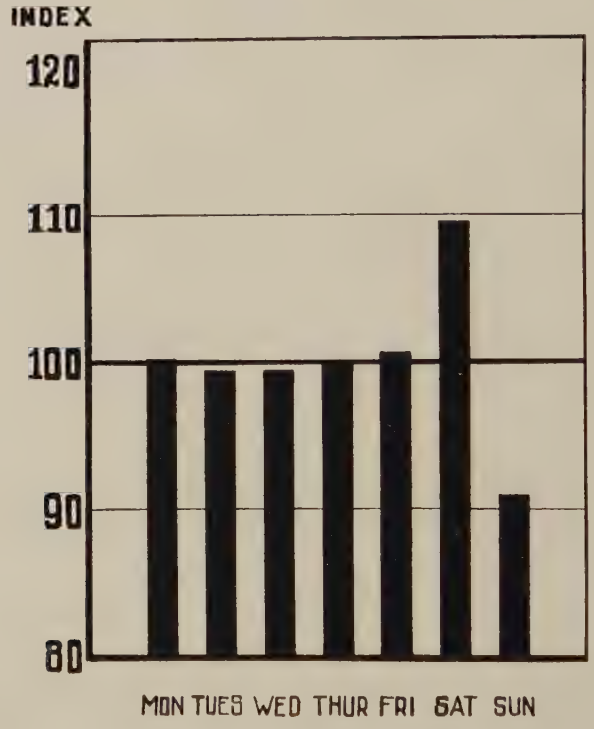

FIGURE 10. Daily variation in the amount of milk sold as whole milk and cream. Use is expressed in percent of the weekly average.

daily variation in market requirements became much more pronounced. (See Figure 11.) However, the daily average for the week-end including Monday was about the same as the daily average for the week.

In order to determine the reason for the variations in total daily requirements for milk, a study of the requirements for individual products was made. Figure 12 shows that whole milk sales were fairly constant from Monday to Saturday and declined on

Sunday. Single-cream sales were not dissimilar, whereas double cream sales were lowest from Tuesday to Saturday and high for Saturday and Sunday. Total figures indicate that the drop in milk and single cream sales are about offset by increased double

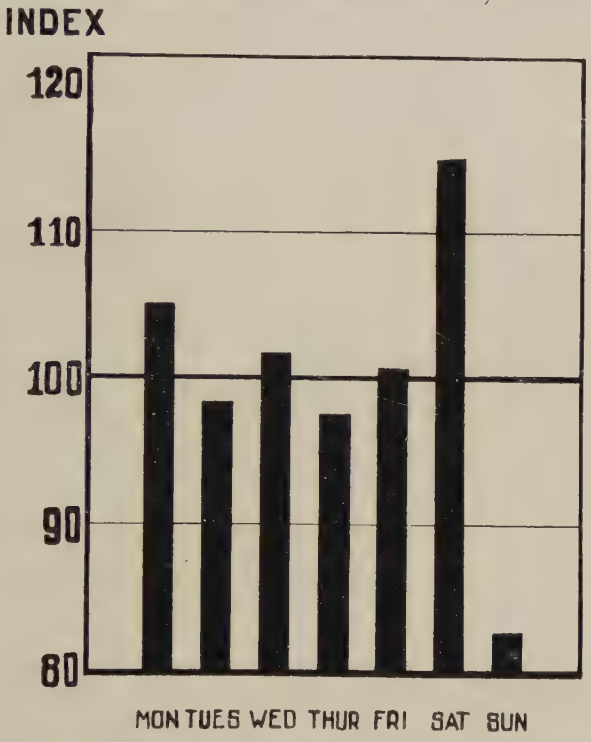

FIGURE 11. Daily variation in the amount of milk sold as whole milk, cream, buttermilk and cottage cheese, 1934-1935. Use is expressed in percent of the weekly average.

cream sales. The decline in the consumption of milk on Sunday seems chiefly due to decreased use by lunch counters and restaurants which serve noon lunch during the week.

Two kinds of cream are sold in Lexington, single cream which tests 18 to 25 percent butterfat and double cream testing 28 to 35 percent, as a rule. In use, the two kinds are more or less interchangeable. In many homes cream is considered a semi-luxury for special occasions, and the demand is irregular. Because of this

fact only a general idea of the nature of the day to day variations can be ascertained. The daily variations for single cream are less marked than those for double cream because it is used in daily menus while double cream is used more for special desserts. It

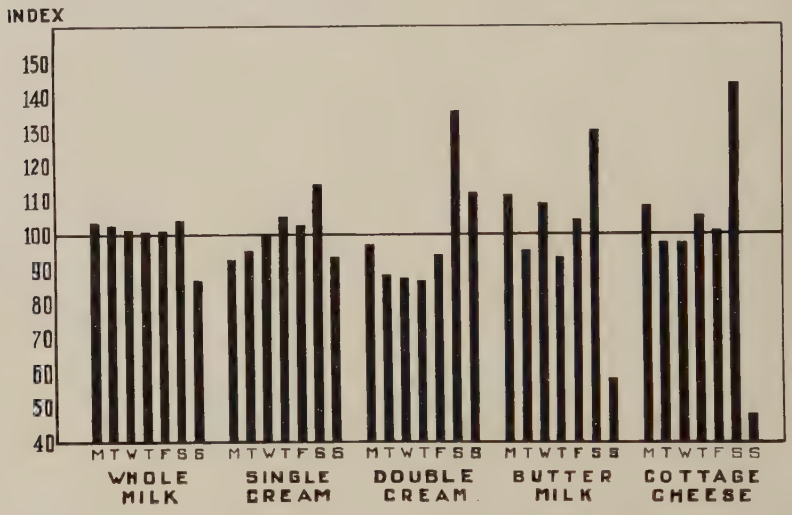

FIGURE 12. Daily variation in the use of certain products in 1934-1935. Use is expressed in percent of weekly average

may be seen from Figure 12 that double cream sales are the heaviest at the week-ends.

Buttermilk is sold largely thru stores and restaurants, much of it in low-income areas. Because it keeps well it can be and is purchased on alternate days as may be seen in Figure 12. The highest sales are on Saturday and Monday.

Cottage cheese shows fairly uniform daily sales for the first part of the week with a marked increase on Saturday and a sharp decrease on Sunday. Much of the characteristic increases in the sale of certain products is the result of purchases made for Sunday uses, and is brought about by the closing of stores on Sunday.

EFFECT OF HOLIDAYS ON CONSUMPTION

Because of the influence of holidays a weekly average figure may cover up much of the irregularity found in the sale of milk products. Variation in holiday demand may affect either the holi-

day, or the preceding day or both, depending upon the source of supply, the day of the week and the intended use. The magnitude of these deviations appears to depend upon the nature and amount of the product used. In many cases the increased use of cream accounts for a large part of the increase in total sales.

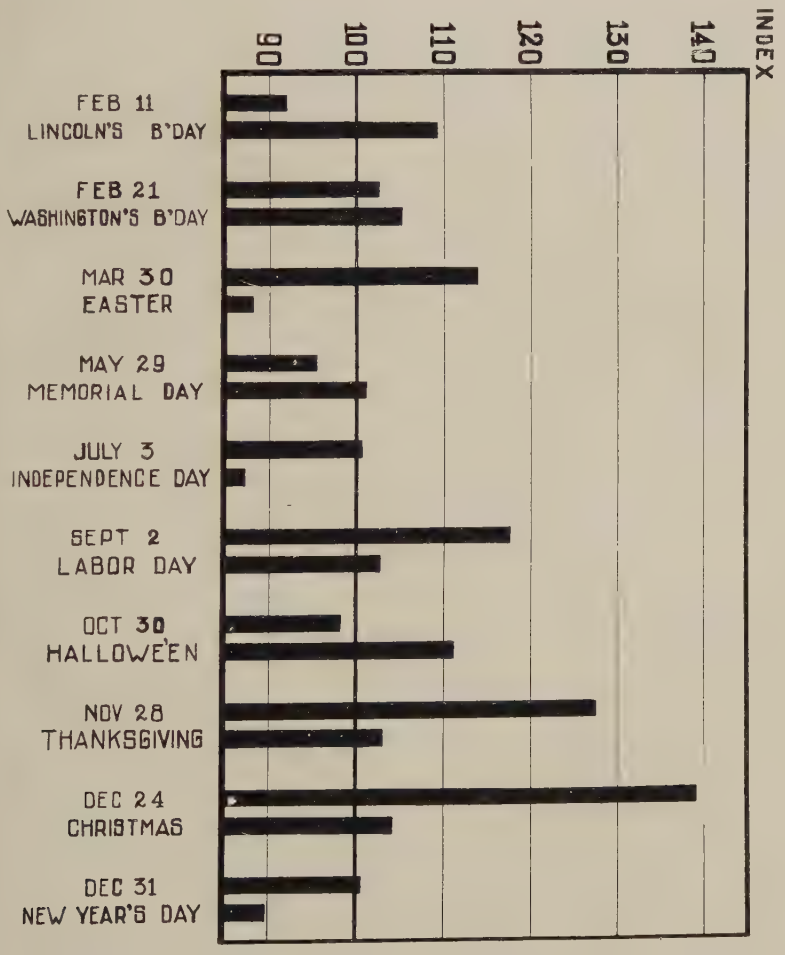

FIGURE 13. Index of sales of milk on certain holidays and on the day preceding each holiday, 1934. The relative amounts for a holiday and the day preceding it were expressed in percent of the average of three days preceding the day previous to the holiday and three days after the holiday. Corrections were made for the day of the week.

A study of Figure 13 shows that there is a marked increase in the total use of milk on Thanksgiving and Christmas, a lesser increase for Washington's birthday and Labor Day, and little or no change for Lincoln's birthday and Easter. Conversely, Memorial Day, Independence Day, and New Year's Day show decreases in the use of milk. It should not be inferred from this that there is not an increased consumption of certain individual products on the days showing decline. For example, an analysis of the records of individual products shows that there is a marked increase in the

Table 9. Spread between purchase and sale prices of milk handled by pasteurizing plants, cents per quart.[1]

Year and Month.	Average Buying Price[2]	Price Spreads			
		Wholesale (In cases of 12 quarts)	Store Trade (Bottled)	Family Trade (Bottled)	Average Spread
1932					
Jan.	4.8	....	7.2	7.2	7.2
Feb	4.6	4.7	6.4	7.1	6.4
Mar.	4.3	3.4	5.7	6.7	5.3
Apr.	4.0	3.7	6.0	7.0	5.6
May	3.6	....	5.4	6.4	5.7
June	3.5	4.5	5.5	6.5	5.5
July	3.1	4.9	5.9	6.9	5.9
Aug.	3.2	4.3	5.8	6.8	5.6
Sept.	3.4	4.6	6.6	6.6	5.9
Oct.	3.5	4.5	6.5	6.5	5.8
Nov.	3.7	4.3	6.3	6.3	5.6
Dec.	3.8	4.2	6.2	6.2	5.5
Ave.	3.8	4.3	6.1	6.7	5.8
1933					
Jan.	3.7	4.3	6.3	6.3	5.6
Feb.	3.6	4.4	5.4	6.4	5.4
Mar.	3.3	4.2	5.7	6.7	5.6
Apr.	3.1	3.9	5.9	6.9	5.6
May	3.0	(a)	4.5	6.0	3.8
June	3.0	....	6.0	7.0	5.6
July	3.1	(a)	4.9	6.9	4.1
Aug.	3.1	3.9	4.4	6.9	4.1
Sept.	3.2	4.8	4.3	6.8	5.3
Oct.	3.5	4.5	5.5	6.5	5.5
Nov.	3.6	4.4	5.4	6.4	5.4
Dec.	3.5	4.5	5.5	6.5	5.5
Ave.	3.3	4.3	5.3	6.6	5.1

Table 9. (Continued.)

Year and Month	Average Buying Price[2]	Price Spreads			
		Wholesale (In cases of 12 quarts)	Store Trade (Bottled)	Family Trade (Bottled)	Average Spread
1934					
Jan.	3.5	4.5	6.5	6.5	5.8
Feb.	3.5	4.5	5.5	6.5	5.5
Mar.	3.5	4.5	5.5	6.5	5.5
Apr.	3.4	4.6	5.6	6.6	5.6
May	3.4	4.6	5.6	6.6	5.6
June	3.4	4.6	5.6	6.6	5.6
July	3.4	4.6	6.6	6.6	5.9
Aug.	3.5	4.5	6.5	6.5	5.8
Sept.	3.7	5.3	6.3	6.3	5.6
Oct.	3.8	5.2	6.3	6.2	5.5
Nov.	4.4	5.6	7.1	7.6	6.7
Dec.	4.5	5.5	7.0	7.5	6.6
Ave.	3.7	4.8	6.2	6.7	5.8
1935					
Jan.	4.5	....	6.5	7.5	6.2
Feb.	4.6	....	5.9	6.4	6.1
Mar.	4.4	5.6	6.6	7.6	6.8
Apr.	4.0	....	5.0	6.5	5.8
May	3.8	....	5.2	6.7	6.0
June	3.7	3.8	5.8	6.3	5.3
July	3.7	4.8	6.3	7.3	6.1
Aug.	3.7	4.8	6.3	6.8	5.9
Sept.	3.7	....	6.3	6.8	5.9
Oct.	3.9	4.6	6.1	6.6	5.7
Nov.	4.1	5.4	6.9	6.9	6.4
Dec.	4.4	5.1	6.6	7.1	6.6
Ave.	4.0	4.9	6.1	6.7	6.1
1936					
Jan.	4.3	5.2	6.7	6.7	6.2
Feb.	4.2	5.3	6.3	6.8	6.1
Mar.	4.2	4.3	5.8	6.8	5.6
Apr.	4.0	....	5.5	7.0	5.5
May	3.7	....	6.3	6.8	5.8
June	3.7	4.8	6.3	6.8	5.9
July	4.2	5.8	6.8	7.8	6.5
Aug.	4.6	5.4	6.9	7.4	5.9
Sept.	4.8	5.2	6.7	7.2	5.7
Oct.	5.1	4.9	6.4	6.9	5.6
Nov.	5.1	4.9	6.4	6.4	5.6
Dec.	5.2	4.8	6.3	6.8	5.5
Ave.	4.4	5.1	6.4	6.95	5.8

[1]Calculated from U. S. D. A. Monthly Fluid Milk Report and from dealers buying price. [2]Weighted average price per cwt. from dealers' records divided by 46.5. (a) Prices ranged as low as five cents per quart during a price war.

use of double cream on New Year's day, but this increase is more than offset by declines in the use of other products.

From the limited information available it also appears that the variation in the use of dairy products is closely related to size of package. For example, the sale of double cream in pint bottles was six times the normal for both Christmas and the preceding day, while the sale of half pints was only about twice normal. Similar conditions but to a lesser degree can be shown for other holidays and for different products. It should be noted that the foregoing figures on the effect of holiday on use were based only on one year's records. Check on similar periods in other years indicate that there may be some variation in the magnitude of the effects, but in general, the characteristics of use are the same.

DEALERS' PRICE SPREADS

Nearly all plant distributors sell milk at both retail and wholesale. The proportion of milk sold in either way varies with individual plants and with the season of the year. Moreover, certain classes of trade such as independent stores buying in full cases or chain stores buying on contract, obtain milk at prices prevailingly lower than the family trade.

Table 9 gives the spread taken by distributors for these different classes of trade on bottled milk by months and years for the period, 1932 to 1936, inclusive. Dealers' spreads were usually lowest and least stable for full-case sales and largest and most uniform for the family retail trade. Margins on the store bottled milk were intermediate.

There was a tendency for the average price spread to widen during the winter but there was no consistent seasonal change in the spread from month to month. The spreads also increased during the five-year period, 1932-1936; the increase was largest for the wholesale trade and least for the family trade. As milk prices were rising during the period under consideration, this relationship between retail and wholesale trade was normal, and reflects the generally greater stability of retail prices.

The years 1932 to 1936 were characterized by rising milk prices, increasing costs of operation and keen competition in the distribu-

tion of milk. Milk plants of the markets did not markedly lose business to producer-distributors except in 1935 (see Table 7), but they sold a smaller proportion of their milk purchases to the bottled-milk trade because of increasing supplies and lower bottled sales. (See Table 10.) We would expect marketing margins to rise in a normally competitive market under these circumstances but in the absence of information on costs and profits of the various business concerns distributing milk, there is no good measure of the adequacy of margins to distributors or of the fairness of margins to producers and consumers.

Table 10. Percent of milk sold in bottles and average spread on quarts.

Year	Percent sold as bottled milk	Average spread, cents per quart
1932	50	5.8
1933	55	5.1
1934	43	5.8
1935	37	6.1
1936	41	5.8

Competition in the milk business appears to have been very keen; the number of market outlets was large and the organization of the market was conducive to high costs of distribution. The location of the different classes of family trade, with low-income areas separating communities of high-income groups, doubtless increased the length of milk routes. In 1936 there were between 80 and 90 milk trucks serving the combined wholesale and retail trade, or approximately one truck for each mile of city streets. Sample counts showed as many as one truck for each five residences on certain streets. In 1933, there were 186 grocery stores, 140 restaurants, 70 soft-drink establishments, 26 drug stores, 12 confectioneries, and 12 miscellaneous places of business, or a total of 446 establishments, buying milk at wholesale; in 1936 there were about 400.

SUMMARY

About a third of all milk used in Lexington and nearly half the milk sold in bottles is handled by producer-distributors who produce and sell raw milk. The remaining two-thirds of the supply is divided between plant-distributors who purchase all their milk from farmers, and producer-pasteurizers who produce milk, operate pasteurizing plants, and purchase supplementary supplies from other dairymen.

Under the present marketing system farmers bargain individually for the sale of their milk and those who sell to pasteurizing plants usually receive a flat price per hundredweight. In the past, this price conformed to Chicago butter prices except in times of extreme shortage or surplus when dealers paid whatever was necessary to get supplies. The price of milk alone does not seem to determine milk production. In the Lexington milkshed there has been a high turn-over in dairymen and it appears that the relative profitableness of other farm enterprises as well as feed and pasture conditions have had a profound effect on the supply of milk.

The consumption of milk is much less variable than the supply. This condition has tended to create surpluses and shortages. During 1932 and 1933 the market as a whole was short of milk at times, but since that time milk supplies have increased. The most serious problem now is the wide seasonal variation in milk production. This problem is intensified by the presence of a large number of distributors, by maldistribution of supplies among distributors, and by non-cooperation between marketing agencies.

A distinctive feature of competition in the sale of milk is the shifting of consumers between producer-distributors and pasteurizing plants. Pasteurizing plants handle a large proportion of the wholesale trade and special and irregular orders. They also supply most of the buttermilk, cottage cheese, and other manufactured products for the market; consequently, their sales fluctuate more widely than do those of producer-distributors. Conversely, producer-distributors sell a high proportion of their milk at retail. Their sales would be fairly stable except for the fact that they

strive for maximum sales during the season of high production. The retail trade in bottled milk and cream, therefore, is highly competitive during the season of flush production. The net result of this competition is to cause a shifting of some customers from pasteurizing plants to producer-distributors during the spring and summer and subsequently their return to pasteurizing plants during the fall and winter.

The 1932-1936 per capita average consumption of milk, cream and buttermilk in Lexington was .56 pint per day as compared with .85 pint for the United States. Buttermilk constituted 21 percent of the daily per capita consumption.

Dealers who pasteurize milk handle nearly 80 percent of the cream and buttermilk sales for the market and also carry a high proportion of the market surplus. Under these conditions the sale of buttermilk makes it possible to utilize skim-milk profitably and partly to offset the disadvantage of carrying a large part of the market surplus.

Kentucky
Agricultural Experiment Station
University of Kentucky
THOMAS P. COOPER, Director

CIRCULAR NO. 46

DISTILLERY SLOP IN CHICK RATIONS

Lexington, Ky.
January, 1937

Summary

The results indicate: (1) that as much as four-fifths of the corn in the mash may be replaced by thick distillery slop fed in separate troughs, which are kept before the birds at all times; (2) that thick slop may be fed successfully when mixed with an all-mash mixture such as was fed in these experiments, in the proportion of one of mash to two of thick slop; and (3) thin slop was not satisfactory to feed as a supplement to the all-mash ration.

Comparison of the quantities of slop consumed per pound of mash saved shows that, except in lot 4, experiment No. 2, the quantity of slop used is approximately the same in all lots, in each trial. In experiment No. 1, the thick slop needed to replace each pound of mash saved was approximately 16 pounds; in experiment No. 3, the maximum was 24.90 pounds with an average of approximately 24 pounds. It should be kept in mind that this thick slop contained only 8.5 to 9 percent solids.

CIRCULAR NO. 46

DISTILLERY SLOP IN CHICK RATIONS

By W. M. INSKO, JR., G. DAVIS BUCKNER, J. HOLMES MARTIN and AMANDA HARMS

On the basis of usual feed consumption, the average Kentucky farm flock requires two tons of feed per year for mature birds and one ton for chicks. On many farms some feed which would otherwise be wasted is picked up by chickens. In addition to utilizing these waste grains and other available feed, chickens are capable of converting into marketable products, many commercial by-products which are readily available. The Kentucky Agricultural Experiment Station has conducted many experiments with poultry to determine the feeding value of such materials as milk and its by-products, ground limestone, tankage, cottonseed meal and some of the fish liver oils. This circular reports the results of feeding trials with distillery slop.

Distillery slop is the liquid which remains after the alcohol has been distilled from the fermented mash in the manufacture of whisky or alcohol from grain. The processes of mashing and fermentation change most of the starch of the grain into alcohol but leave the protein, fat, fiber and mineral matter practically unchanged. Some of this material is in solution in the liquid, but the larger part is in the form of particles that can be recovered by filtering. A common practice is to filter out as much of the suspended material as practicable, dry it, and sell it as a feed for livestock. This product is the commercial feed known as distillers' dried grains. The liquid which passes thru the filter is called "strained" or "thin" slop. It contains about 96 percent of water. Slop that has not been filtered is "whole" or "thick" slop. It contains about 92 percent of water. Some distilleries dispose of whole slop directly to farmers.

Distillery slop has been used on a large scale, successfully, for feeding cattle, and some farmers in the vicinity of a distillery

find it profitable to haul slop to their farms for feeding livestock; therefore it was deemed desirable to test it as a feed for chickens. The slop used in the experiments reported in this publication was obtained from a Lexington distillery and was made from mash which contained approximately three times as much corn as other grain.

Preliminary trials with battery-raised chicks showed that thin distillery slop fed as a supplement to a satisfactory all-mash ration was not of sufficient value to warrant its use. It was further noted that this slop was not a satisfactory substitute for water.

Method. For the first four weeks the chicks were kept in a Buffalo battery brooder, having compartments three feet square and ten inches high, heated by hot water. At the end of this time, in order to allow more floor space per chick, they were transferred to larger, unheated batteries in a room at approximately 80° Fahrenheit. A 25-watt bulb gave light at night. The chicks received no direct sunlight. Rhode Island Red chicks from the Experiment Station flock were used in all experiments.

EXPERIMENTS WITH THICK SLOP

The plan of this experiment was to substitute thick slop for part or all of the corn in an all-mash ration. The basal mash was composed of mixed wheat feed 25 pounds, dried skim-milk 10 pounds, meat scrap 7.5 pounds, soybean oil meal 5 pounds, alfalfa leaf meal 2.5 pounds, salt 1 pound and fish liver oil 1.2 pounds or its equivalent. This basal mash was supplemented by ground yellow corn mixed with the mash and by thick distillery slop fed in separate metal troughs. Table 1 shows the kind of feed given to each lot. Three experiments were carried out, in the same way but at different times.

Table 1. Composition of the Feed Given to Each Lot. Pounds

Ingredients	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
Basal mash	43.0	43.0	43.0	43.0	43.0
Ground yellow corn	57.0	26.0	9.9	none	57.0
Thick distillery slop	none	ad lib	ad lib	ad lib	200.0

The feed for lot 5 was composed of one part of the total all-mash and two parts of thick slop mixed and kept before the chicks at all times. The corn was mixed with the basal mash for the other lots and the all mash and thick slop were fed in separate containers kept before the chicks at all times. Lots 1 and 5 also received water at all times. Lots 2, 3 and 4 depended upon the water in the slop, and were not given water separately.

The analyses of the mash and slop fed the five lots during the three trials showed very little variation. The following table shows the analyses of the mashes and slop fed in the second experiment.

Table 2. Analyses of Mashes and Thick Slop Fed in the Second Experiment. Percent.

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5*	Thick Slop
Protein	17.3	20.0	22.1	26.1	7.1	2.0
Fat	4.5	4.7	5.5	6.6	2.0	0.7
Fiber	3.6	4.0	5.3	5.6	1.8	0.9
Ash	5.7	7.7	9.8	10.7	2.1	0.3
Total solids	....	....	....	....	....	8.7
Calcium (Ca)	0.9	1.2	1.6	1.6	0.3	0.01
Phosphorus (P)	0.8	1.1	1.2	1.3	0.3	0.05

* Wet mixture of one part of same mash and corn mixture as fed lot 1 and 2 parts of thick slop. Analysis computed from the analyses of the mash, grain and slop.

It will be noted that there was a gradual increase in the percentage of protein in the mash as the quantity of ground yellow corn added to the basal mash was diminished. In the lots which received distillery slop, the chicks seem to have balanced the ration by consumption of the slop.

Results. Results of the three trials indicate that thick distillery slop fed *ad libitum,* may be used to advantage to replace a portion or all of the ground yellow corn in the mash fed growing chicks. Especially good growth was obtained in the first and third trials. The smallest average weight in each trial was that of lot 1, the control group; the largest that of lot 3 in the feed of which 47.1 pounds of corn were replaced by distillery slop.

Table 3. Average Weight of the Chicks at 10 Weeks of Age. Pounds

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
Males					
1st Experiment	1.92	2.24	2.45	2.34	.....
2nd Experiment	1.64	1.93	1.95	1.93	2.22
3rd Experiment	1.91	2.05	2.38	2.12	.....
Females					
1st Experiment	1.74	1.86	1.99	2.02	.....
2nd Experiment	1.45	1.72	1.71	1.62	1.75
3rd Experiment	1.70	1.95	2.21	1.86	.....

The chicks of lot 5, fed a mixture of 1 part of the same feed as fed lot 1 with 2 parts of thick slop weighed more than those of any other lot in the second experiment. This mixture was used in only one trial.

These results indicate (1) that thick distillery slop fed *ad libitum* may be used to replace corn in an all-mash ration; (2) that in this particular mash as much as four-fifths of the corn may be replaced, with excellent results; and (3) that thick slop may be fed successfully when mixed with an all-mash mixture such as that used in this experiment, in the proportion of one of the all-mash to two of thick slop.

Table 4. Weight of Mash, Thick Slop and Total Solids Consumed per Chick to Ten Weeks. Pounds.

Lot	Experiment No. 1			Experiment No. 2			Experiment No. 3		
	Mash	Thick Slop	Total Solids	Mash	Thick Slop	Total Solids	Mash	Thick Slop	Total Solids
1	5.15	.....	.....	4.07	.....	.....	5.56	.....	.....
2	4.25	17.93	5.81	4.16	15.75	5.53	4.96	18.39	6.56
3	4.63	24.11	6.73	4.08	27.43	6.47	5.32	21.94	7.23
4	4.38	32.12	7.17	4.22	24.34	6.34	4.56	27.85	6.98
5	.....	.....	.....	5.71	11.42	6.70	.....	.....	.....

As the proportion of corn in the all-mash ration decreased, the consumption of slop increased, except in lot 3 of experiment No. 2, altho the consumption of mash was not affected consistently.

A comparison of the feed consumed per pound of weight at ten weeks of age, table 5, shows a definite decrease in the quantity of mash as the quantity of slop consumed increased except in lot 4, experiment No. 2. It is worthy of note that the gains in all lots, with this exception, were relatively efficient. Lot 5, experiment No. 2, consumed more mash than the other lots, but the proportion of mash and slop was fixed by the mixing process.

Table 5. Feed Consumption per Pound of Weight of Chickens, at Ten Weeks of Age.

Lot	Experiment No. 1			Experiment No. 2			Experiment No. 3		
	Mash	Thick Slop	Slop used per lb. of mash saved	Mash	Thick Slop	Slop used per lb. of mash saved	Mash	Thick Slop	Slop used per lb. of mash saved
1	2.89	.....	.....	3.04	.....	.....	3.01	.....	.....
2	2.26	9.53	15.13	2.64	9.98	24.95	2.62	9.71	24.90
3	2.17	11.29	15.68	2.46	12.02	20.72	2.51	11.63	23.26
4	2.00	14.59	16.39	2.80	16.15	67.29	2.40	14.57	23.89
5	.....	.....	.....	3.20	6.40	.....	.....	.....	.....

Comparison of the quantities of slop consumed per pound of mash saved shows that, except in lot 4, experiment No. 2, the quantity of slop used is approximately the same in all lots, in each trial. In experiment No. 1, the thick slop needed to replace each pound of mash saved was approximately 16 pounds; in experiment No. 3, the maximum was 24.90 pounds with an average of approximately 24 pounds. It should be kept in mind that this thick slop contained only 8.5 to 9 percent solids.

The number of chicks at the beginning was: 1st experiment, 36 in each lot; 2nd, 50 in lots 1 and 2; 49 in lots 3 and 4; and 45 in lot 5; and 3rd, 50 in each lot. The mortality of

Table 6. Mortality Percentage for 2 Weeks and 10 Weeks.

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
First and second weeks					
1st experiment	11	8	8	6	....
2nd experiment	22	20	6	18	9
3rd experiment	12	14	2	2	....
First to Tenth Weeks					
1st experiment	14	17	19	19	....
2nd experiment	28	40	22	39	31
3rd experiment	12	22	14	12	....

chicks in experiment No. 2 was unusually high during the first and second weeks. This was caused by unavoidably overheating the brooder room.

Quality of the Broilers. Since the final judgment on broilers is determined by their appearance and flavor when served as food, four chicks in each lot of experiment No. 2 were prepared and judged.* One pullet and one cockerel of each lot were oven-broiled and one of each pan-broiled. A committee with some experience in this type of judging, placed the birds from each group. Consideration was given to appearance, tenderness, moistness and flavor. The lots prepared in the two separate ways were rated as follows: 1st, lot 5; 2nd, lot 1; 3rd, lot 2; and 4th, lots 3 and 4. All lots were above average in tenderness and flavor. The chief differences were probably determined by the amount of fat present. Lot 5 which received mash mixed with distillery slop had an exceptionally high percentage of fat, as did lot 1, which received the all-mash alone. It should be emphasized, however, that all chickens tested were exceptionally tender and of good flavor.

* The authors are indebted to Miss Edith Grundmeier, of the Home Economics Department, under whose direction the chickens were prepared and judged.

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CONTROL OF INSECTS COMMONLY AFFECTING TOBACCO PLANT BEDS.

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CIRCULAR NO. 47

Control of Insects Commonly Affecting Tobacco Plant Beds.

By

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Tobacco plants in beds are subject to attack by a number of insects, some that live in the soil and others that migrate into the beds. Beds need constant attention in order to detect the presence of any of several insects that at times attack the plants. When plants are very small, even slight injury may deform them or check their growth permanently, and there is also the possibility that insects may introduce certain diseases. No single method of control can protect plants in beds and it is necessary at times to resort to insecticides in the form of sprays, dusts, baits or fumigants and to mechanical barriers. A study of methods to control some important pests of the beds was begun in 1934 in order to determine practical control measures.

SOIL INSECTS

Several insect larvae that live in the soil are capable of doing considerable damage to plants in the beds. Soil that has not been in cultivated crops for some time is more likely to be infested by such larvae. Common white grubs, Fig. 1, cutworms, and the larvae of the green June beetle, Fig. 2, are most frequently noticed. White grubs become numerous in pastures and sod land and are active in the soil one or more years. They feed on the roots of grasses and other plants. The grubs of the green June beetle feed on decaying vegetable matter on or near the surface of the soil and do very little injury by feeding on the roots of plants. These grubs become very active in the

spring and do most of their feeding near the surface of the soil because most of the humus is found there. Sometimes the surface of the soil becomes thoroly pulverized by the burrowing of the grubs in their search for food. Serious damage may be done by uprooting and covering very young tobacco plants in the beds. The grubs of the green June beetle complete their development within a year.

Control Measures. The control of grubs and other soil insects is difficult. The site for a tobacco bed should be selected in the early fall, at a place where examination shows few or no grubs in the soil. If this is not practicable, the bed should be prepared in early fall and remedial measures applied immediately, because later in the season, grubs and other larvae move too deep into the soil to be reached. Generally, tobacco beds are prepared in the spring and are steamed or burned. Burning has been practiced for many years, to kill weed and grass seed near the surface of the soil, and it is generally believed that this practice is helpful in controlling soil insects. In this connection, white grubs were used in tests to determine the amount of control effected by steaming and burning of beds.

WHITE GRUBS

Effect of Steaming and Burning Beds. The degree of control of white grubs by steaming or burning beds is undoubtedly

Fig. 1. A species of White Grub found in tobacco beds (enlarged 1½ times).

affected by the mechanical condition of the soil, its moisture content and temperature; also, the pressure of steam and the length

of time of steaming, and the amount and kind of wood used in burning a bed are important factors. When beds are prepared in the spring, many of the grubs are still too deep in the soil to be affected by the heat from burning or steaming. To determine the measure of control effected by burning or steaming a bed, grubs were placed at different depths in the soil just before treatment and were removed as soon as the soil had cooled.

Steaming. White grubs placed at depths of 4, 6, 8, and 10 inches in the soil in a bed steamed on March 24, 1934, were all killed. Twenty-five grubs were placed at each depth, but no replications were made. The soil in the bed was loose and dry for the time of the year. Steam was applied for 30 minutes, at about 80 pounds pressure in the boiler. To judge from this one test, steaming was more effective than burning.

Burning. In each test, five lots of grubs were placed at each depth in the soil, before the beds were burned. They were examined afterwards as soon as the soil had cooled. The average results are given in Table 1. In 1934 each lot was of 10 grubs; in 1935, 20, and in 1936, 25. Especial care was used in arranging the wood on the bed so it would burn well and it is likely that more was used than is generally the case. The less favorable results obtained in 1936 were very likely due to excessive moisture in the soil and poor quality of the wood. The depth to which the heat penetrates varies greatly with the kind of fire and the condition of the soil. Probably most of the grubs are killed to about 4 inches depth, but many may remain alive below that depth.

TABLE 1. Percentage of white grubs killed at different depths in burning a tobacco bed. Each figure is the average of 5 tests, with 10 to 25 grubs each.

Depth in the soil Inches	1934 Percent	1935 Percent	1936 Percent
3	.....	100	93.6
4	100	95	48.0
5	.....	.....	16.0
6	100	60	4.0
8	60	10	.....
10	12	.....	.....

GREEN JUNE BEETLE GRUB

Carbon Disulfide Fumigation. Grubs of the green June beetle were rather numerous in the soil in several beds examined in the spring of 1935. Some beds were practically destroyed by the larvae, while others were only slightly damaged. Both liquid carbon disulfide and an emulsion of this substance were used in the tests.

Procedure. On April 24, 1935, liquid carbon disulfide was applied to 90 square yards of a bed by placing the liquid in holes made by the larvae or made with a rod. A large pipette was

Fig. 2. The larva of the Green June Beetle (enlarged 1½ times).

used to inject one teaspoonful of the liquid into each opening, at depths of 4 to 8 inches, and the openings were closed afterwards. The maximum dosage was 1.5 ounces to a square yard.

Results of the treatment. The treatment was satisfactory in stopping the activity of the larvae and no injury to the plants resulted. It was not possible to dig out all the larvae, but from examination of 216 openings, only 3.3 percent showed any signs of activity of the larvae. The bed in which the larvae were found had been steamed in October, 1934.

Carbon Disulfide Emulsion. Diluted carbon disulfide emulsion was applied to one plant bed on May 10, 1935. The diluted emulsion was made by adding 1 quart to 50 gallons of water of a standard emulsion containing 70 percent carbon disulfide. The diluted emulsion was distributed on the bed thru a hose, at the rate of 16 pints to the square yard.

Results of the treatment. The bed was examined several times after the treatment and, as nearly as could be determined, about 30 percent of the larvae were killed. The usual dosage for treating sod for controlling grubs is 27 pints of diluted emulsion to the square yard. In this bed, even with a very light treatment, many of the plants were killed or injured; also, there was very little control of the larvae.

Poisoned Bran Bait. This was suggested by K. B. McKinney and Joe Milam (1) for controlling larvae of the green June beetle. It was made of 25 pounds of bran, 1 pound of paris green and enough water to moisten. The moisture content of bran varies somewhat, but about 4.5 gallons of water is a minimum amount to 25 pounds of bran. The bait usually is used at the rate of 10 to 12 pounds to 100 square yards of plant bed. This bait was used in several tests.

Procedure. Several large trays were filled with screened soil and on these fifteen or twenty larvae were placed. They burrowed in immediately. The soil was then sprinkled lightly with water and the bait was scattered on the surface, the day following. The bait was used at the rate of 4, 5, and 6 pounds dry weight to 100 square yards. The dry weights corresponded to practically 9.5, 12, and 14.5 pounds of moist bait. There were 10 replications of each treatment. A check of 100 larvae was used for each treatment. A daily record was kept of the number of larvae found dead on the surface of the soil and on the sixth day the soil was examined for dead and live larvae. The bait was applied September 7, 1936.

Results of the treatment. The bait was not effective in controlling the larvae at any of the dosages. For the 4-pound applications, the percentages of larvae killed ranged from 8 to 24, with an average of 14.8. There was no mortality in the check.

The percentages killed by the 5-pound applications ranged from 10 to 30, with an average of 18. There was a mortality of one percent in the check. The 6-pound applications gave some control of the larvae, but it was too poor to be effective. The percentages killed ranged from 40 to 65, with an average of 54.9. There was no mortality in the check.

SPRINGTAILS

The springtail, *Bourletiella hortensis* Fitch, Fig. 3, was found injuring very young plants in a tobacco bed on the Station farm in the spring of 1934. Because of its habit of jumping and its shape and color, farmers generally call this insect a flea. The insect was very numerous and had apparently migrated into the bed from a field of lespedeza near by. In the spring of 1935, another species, *Isotoma viridis* Bourlet, was found in a tobacco bed, but so few were present that no control measure was used.

The bed infested by *Bourletiella hortensis* was treated with nicotine sulfate with very good results. A solution of 1 part of

Fig. 3. The Springtail, *Bourletiella hortensis* Fitch (enlarged 15 times).

40 percent nicotine sulfate solution to 800 parts of water, was applied with a sprinkling can on May 4, and by May 7 only an occasional specimen could be found. The covering on the bed was removed before applying the solution and was immediately replaced thereafter. The solution was applied at the rate of 5 gallons to 30 square yards of the bed. As nearly as could be determined by examining plants and screening some of the soil from the surface of the bed, 97.9 percent of the insects were killed by the treatment.

THE TOBACCO FLEA BEETLE

The tobacco flea beetle, *Epitrix parvula,* Fig. 4, is generally considered one of the most destructive pests of tobacco, both in the bed and in the field. In the bed, young plants may be injured so severely that they become deformed or weakened or die from injury, and in the field, newly transplanted plants are greatly hindered in becoming established and make slow growth. Leaves of tobacco which might be suitable for cigar wrappers

Fig. 4. The Tobacco Flea Beetle, *Epitrix parvula* (enlarged 20 times).

may be rendered unfit for this use. During the past three seasons, this beetle has not been very destructive to plants in the beds on the Experiment Station farm. It did considerable damage, however, to some of the tobacco shortly after being transplanted.

Several insecticides have been recommended for controlling or partially controlling the tobacco flea beetle on plants in beds and fields, and there are several recent reports on control measures. E. G. Beinhart (2) recommends for use on plant beds, a spray made of 50 gallons of Bordeaux mixture, 2 pounds of lead arsenate, and 1 pint of 40 percent nicotine sulfate solution. F. S. Chamberlin (3) advises the use of a mixture of barium fluosilicate 8 parts, infusorial earth 2 parts, and finely ground tobacco dust 2 parts or the infusorial earth may be omitted.

This mixture was to be used on shade-grown tobacco in Georgia and Florida. W. H. White (4) reports that barium fluosilicate used at the rate of ½ pound to 100 square yards of tobacco bed, and derris mixed with tobacco dust and containing 2 percent rotenone, when used at the rate of 1 pound to 100 square yards of tobacco bed, are equally effective. Irene D. Dobroscky (5) states that a natural cryolite and talc mixture of a 40–60 percent strength may rightly be said to be specific for the tobacco flea beetle. W. W. Stanley and S. Marcovitch (6) recommend the use of a barium fluosilicate compound or calcium arsenate for controlling tobacco flea beetles.

Control of the Flea Beetle in Plant Beds. In 1934, 1935 and 1936 several insecticides were tried for controlling the beetle in tobacco plant beds. Portions of beds were also enclosed by board frames covered with a good grade of tobacco cotton, Fig. 7, to determine the degree of protection given by this device. Results obtained from the use of the different measures were compared in order to find the most effective measure for protecting the plants.

General procedure. The insecticides were applied in sections 5 feet wide across the plant bed, with arrangement for five replications of each treatment. The sprays were applied with a compressed-air sprayer and the dusts with a plunger type of duster. When insecticides were being applied, the portions of the bed not being treated were covered with canvas tarpaulins to give protection from drifting materials. Applications of the different insecticides were all made the same day. Injured plants were counted in 5 samples for each replication, making 25 samples for each insecticide. Samples were taken at random and included all the plants enclosed in a wire loop 1 foot square.

The sprays were applied at the rate of 1 gallon to 30 square yards, and the dusts at the rate of ½ pound to 100 square yards except 1 pound for the derris dusts. The barium fluosilicate dust contained 80 percent of barium fluosilicate and 20 percent of inert material. The synthetic cryolite dust contained 40 percent of synthetic cryolite and 60 percent of infusorial earth.

The derris dusts were made of ground derris root and infusorial earth and contained 1 and 2 percent rotenone.

The beds in which the insecticides were tested, and the controls, were covered in the usual way; that is, the cotton cloth was stretched over wire loops in the beds and pinned to the ground with wires or pegs, along the edges, Fig. 5. This method gives little protection against insects. The average results of the treatments are given in Table 2.

TABLE 2. Percentage of tobacco plants injured by the tobacco flea beetle, in the bed, under different treatments. Each figure is the average of 5 counts of each of 5 similar experiments.

Treatment	1934 Percent	1935 Percent	1936 Percent
Bordeaux mixture 3–3–50, 50 gals.; lead arsenate 2 lbs.; 40 percent nicotine sulfate solution, 1 pint	22.9	15.5	.....
Same without nicotine sulfate	29.2	20.2	.....
Cuprous cyanide, 2½ lbs.; water, 100 gals.	.....	25.5	.....
Barium fluosilicate dust	12.7	13.3	15.5
Paris green, 1 part; lead arsenate, 4 parts; hydrated lime, 1 part (dust)	24.6	.....	.....
Synthetic cryolite dust	.....	.....	19.1
Derris dust, 1 percent rotenone	.....	.....	27.8
Derris dust, 2 percent rotenone	.....	.....	27.1
Control (loose cover, no treatment)	44.3	31.5	32.0
Boxed, tight cover, no treatment	5.0	1.5	2.2
Insecticides applied, May	16th 22nd	14th 25th	7th 15th

Results of the treatments. Bordeaux mixture containing lead arsenate is frequently recommended for controlling flea beetles. The addition of nicotine sulfate is said to increase the efficiency of the combination (2). The Bordeaux mixture and lead arsenate combination with and without nicotine sulfate was used in 1934 and 1935. Comparison of results shows some difference in favor of the addition of nicotine sulfate; the difference, however, is not very significant. Both treatments reduced flea beetle injury considerably, but did not give sufficient control. A dust mixture made of paris green 1 part, lead arsenate 4 parts and hydrated lime 1 part was tried in 1934. This mixture gave

about the same amount of control as the Bordeaux mixture, lead arsenate and nicotine sulfate combination, used the same season. Cuprous cyanide as tried in 1935 gave practically no control. The derris dusts as used in 1936 gave practically no control. Derris dusts of 1 or 2 percent rotenone content, when fresh, kill the beetles but soon lose the power to kill, so they give little control unless applied frequently. The barium fluosilicate mixture gave better control than any other insecticide tried, in all three seasons. In 1934, control was significantly better than that of any of the other insecticides used, but in 1935, control was only slightly better than that of the Bordeaux mixture with lead arsenate and nicotine sulfate. In 1936, barium fluosilicate was more effective than the synthetic cryolite dust and derris dusts.

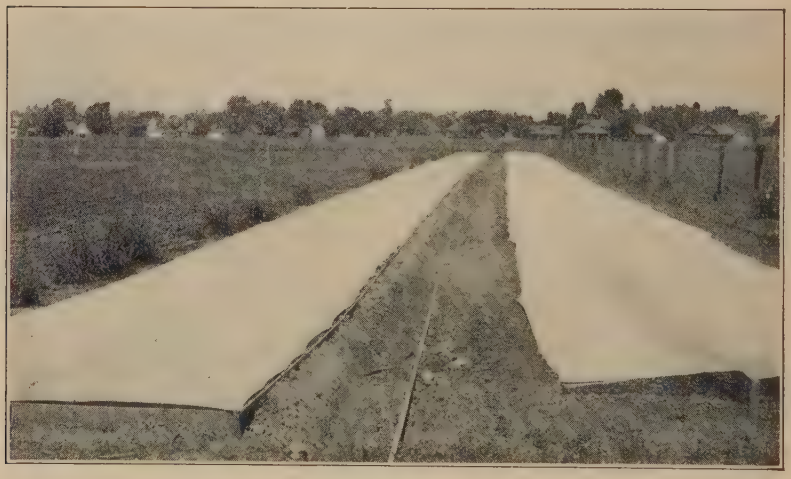

Fig. 5. These coverings give practically no protection from insects.

For three seasons, the portions of beds that were protected by board frames covered tight with cloth, Fig. 7, showed the least injury of any of the treatments. The protection given by this device was significantly better than that by the most efficient of the insecticides.

CONCLUSIONS ON TOBACCO FLEA BEETLE CONTROL

During three years' study a barium fluosilicate dust containing 80 percent of barium fluosilicate was found to be the most efficient insecticide. It was applied at the rate of ½ pound on 100 square yards of bed.

The most effective measure was the use of a well-constructed barrier around the bed, consisting of a well-fitted board frame covered tight with a good grade of tobacco cotton. A few beetles may be able to get into the bed, but the protection is significantly

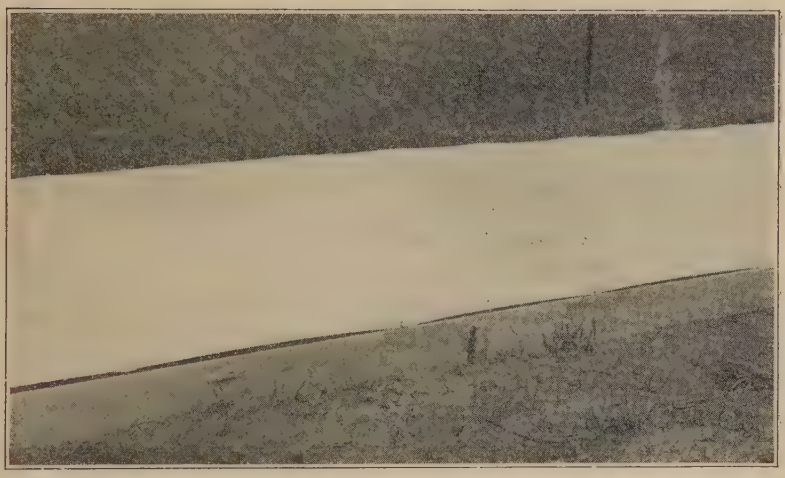

Fig. 6. The tobacco cotton is too loosely fastened to the frame to keep out insects.

greater than that of the most effective insecticide tried. When the cloth was fastened as shown in Fig. 6, protection was not so good.

The cost of six-inch boxing lumber and enough creosote for brushing or painting the lumber amounts to about $8.00 at the present prices, for a bed 9 feet wide by 100 feet long. A bed this size would furnish plants for 3 acres or more of tobacco. The boards, if given proper care, should last for 4 years or longer; the cost, therefore, distributed over a period of 4 years,

would be small in comparison to the amount of protection given. The cost of insecticides and labor in applying them, where a bed

Fig. 7. The tobacco cotton is so fastened to the frame that few insects can enter the bed.

is not boxed and covered, would be about the same as that of the materials used in the construction of a boxed bed.

SUMMARY

Burning a tobacco bed effects only partial control of grubs in the soil. If the bed is well burned, nearly all grubs are killed in the upper 3 or 4 inches of soil; however, beds usually are burned early in the spring, when grubs are too deep in the soil to be reached.

Larvae of the green June beetle can be controlled in beds by injecting liquid carbon disulfide into the soil. An emulsion of carbon disulfide gave little control of the grubs and injured a considerable percentage of the plants. Poisoned bran bait applied at the rate of 6 pounds dry weight to 100 square yards of bed, in the insectary, killed about 55 percent of the grubs.

A mixture of 1 part of a 40 percent solution of nicotine sulfate to 800 of water gave good control of the springtail, *Bourle-*

tiella hortensis Fitch, when applied at the rate of 5 gallons to 30 square yards.

A barium fluosilicate dust containing 80 percent of barium fluosilicate applied at the rate of ½ pound to 100 square yards of bed, was the most efficient insecticide tried for controlling the tobacco flea beetle, *Epitrix parvula,* in beds.

A good board frame with a tight cover of a good grade of tobacco cotton protects plants from most of the flea-beetle injury. During three years of light infestation, this method was the most satisfactory single method of protecting plants in the bed. To construct a good boxed bed, the boards should be set in the soil an inch or two or the soil should be banked on the outside of the boards and tamped. The cloth should then be drawn down the outside edges of the boards and fastened by small nails or with thin strips of wood.

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THE VALUE OF LEAF MEALS OF ALFALFA, KOREAN LESPEDEZA AND LESPEDEZA SERICEA IN ALL-MASH CHICK RATIONS

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The Value of Leaf Meals of Alfalfa, Korean Lespedeza and Lespedeza Sericea In All-Mash Chick Rations

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It is considered good practice by many poultry raisers to include alfalfa leaf meal or ground alfalfa hay in mashes for chicks and laying hens. These alfalfa products, when properly cured, are excellent sources of vitamins A and G, and contain 14 to 21 percent protein. The quantities usually recommended vary from 2 to 5 percent of the mash. Wisconsin investigators recommend that "a farmer who purchases alfalfa leaf meal, but raises the grain needed for a poultry ration, will probably find it most economical to use not more than 5 percent of alfalfa in the mash. On the other hand, one who grinds his own alfalfa hay for poultry feeding may want to use 10 percent."

It has been estimated that 3,000,000 acres of Korean lespedeza, 135,000 acres of alfalfa and 10,000 acres of lespedeza sericea were grown in Kentucky during the year 1936. Because of the increasing popularity of these legumes, the question is frequently asked, What are their comparative feeding values?

The experiment to be described is concerned with the determination of the practical use and comparative value of the leaf meals of alfalfa, Korean lespedeza and lespedeza sericea in a mash fed to White Leghorn chicks in an indoor battery brooder. To obtain this information mashes containing these leaf meals were compared with a mash which contained yellow corn 57, soybean meal 4, mixed wheat feed 22, dried skimmilk 9, meat scrap 6, salt 1, and sardine oil 1 percent. This mash which had given good rates of growth repeatedly, was formulated so that the quantities of skimmilk (35.5% protein) and meat scrap (53.5% protein) used, contained approximately the same quantity of protein.

In addition to investigating the value of these leaf meals in all-mash rations for growing chicks, the rations were prepared in such a way that information could be obtained concerning the compara-

Table 1. Composition of the mashes fed each lot. Percent.

Lot No.	Ground yellow corn	Corn starch	Soy-bean meal	Mixed wheat feed	Dried skim-milk	Meat scrap	Korean leaf meal	Alfalfa leaf meal	Sericea leaf meal	Tri-calcium phosphate	Salt	Sar-dine oil
1	57	—	4	22	9	6	—	—	—	—	1	1
2	57	5.5	4	—	9	6	16.5	—	—	—	1	1
3	57	4.4	4	—	9	6	—	17.6	—	—	1	1
4	57	4.4	4	—	9	6	—	—	17.6	—	1	1
5	52	—	4	—	9	—	31	—	—	2	1	1
6	57	—	4	—	—	6	31	—	—	—	1	1
7	50	—	4	—	9	—	—	33	—	2	1	1
8	55	—	4	—	—	6	—	33	—	—	1	1
9	50	—	4	—	9	—	—	—	33	2	1	1
10	55	—	4	—	—	6	—	—	33	—	1	1
11	53	—	4	—	9	—	11	10	11	—	1	1

Table 2. Analyses of the mashes fed to the chicks. Percent.

Lot No.	Protein	Fat	Fiber	Nitrogen-free extract	Water	Ash	Cal-cium	Phos-phorus
1	17.3	3.6	2.9	63.4	7.2	5.6	.8	.8
2	17.0	4.0	8.1	56.6	8.3	6.0	1.2	.6
3	16.9	3.8	6.2	58.9	7.4	6.8	1.0	.7
4	17.1	4.4	7.9	57.8	7.0	5.8	.9	.5
5	16.9	4.7	8.2	56.3	8.0	5.9	1.1	.6
6	17.4	4.7	8.9	57.1	6.1	5.8	1.1	.7
7	17.0	3.9	5.8	59.5	6.8	7.0	1.4	.6
8	17.2	4.4	5.6	58.5	7.2	7.1	1.1	.5
9	16.5	4.3	8.5	59.0	6.2	5.5	.8	.5
10	16.8	4.9	8.5	57.6	6.0	6.2	1.0	.6
11	17.1	4.9	7.8	56.2	7.5	6.5	.9	.5

tive biological values of the proteins in these leaf meals as compared with equal quantities of proteins in meat scrap or dried skimmilk.

With these objects in view, 11 lots of 50 day-old White Leghorn chicks were weighed individually, on the first day and every two weeks thereafter for eight weeks. These lots of chicks were placed in separate compartments of battery brooders of the usual type and fed the all-mash rations given in Table 1.

Lot 1 received the control ration as previously stated and the rations fed to lots 2, 3, and 4 were prepared so that leaf meals of Korean lespedeza, alfalfa or lespedeza sericea, plus the amounts of cornstarch indicated in the table, replaced the 22 parts of mixed wheat feed contained in ration 1. The quantities of leaf meals used were based on the estimated percentages of protein contained in each, and contained the same amount of protein as the mixed wheat feed replaced. The cornstarch was added to compensate for the smaller amount of nitrogen-free extract and larger amount of fiber

Table 3. Effect of substituting alfalfa or lespedeza leaf meal for certain components of the dry mash fed to chicks during 8 weeks.

Lot and kind of leaf meal	Average weight		Mortality	Feed consumed average per chick
	Females Grams	Males Grams	Percent	Pounds
In place of wheat feed.				
2. Korean	466	501	8	3.1
3. Alfalfa	450	490	6	3.0
4. Sericea	472	491	10	3.2
Average	463	494	8	3.1
1. Control	470	481	10	3.4
In place of wheat feed and meat scrap and part of the ground corn.				
5. Korean	315	342	9	3.0
7. Alfalfa	292	346	20	3.1
9. Sericea	310	351	10	2.7
11. All together	303	342	5	2.8
Average	305	345	11	2.9
1. Control	470	481	10	3.4
In place of wheat feed and dried skimmilk and part of the ground corn.*				
6. Korean	242	262	9	2.9
8. Alfalfa	241	260	18	2.8
10. Sericea	239	281	5	2.7
Average	241	268	11	2.8
1. Control	470	481	10	3.4

* Except No. 6, which had the full quantity of ground corn.

contained in the leaf meals as compared with the mixed wheat feed which they replaced in the ration.

In lots 5, 7, and 9, leaf meals of Korean lespedeza, alfalfa and lespedeza sericea and in lot 11 a mixture of the three, replaced the meat scrap, mixed wheat feed and part of the ground corn in ration 1, so that the quantities of protein in the leaf meals were the same as that in the meat scrap, mixed wheat feed, and corn replaced. To the feeds which contained no meat scrap, 2 percent of tricalcium phosphate was added to compensate for the quantity of calcium and phosphorus contained in the meat scrap.

In like manner, in lots 6, 8, and 10, respectively, the leaf meals replaced the dried skimmilk and mixed wheat feed, and also part of the ground corn in lots 8 and 10.

Table 2 contains the analyses of the mashes fed to the 11 lots, and shows that there were no great differences in the quantities of protein and other constituents, except fiber. Table 3 gives the average weight of the chicks in each lot at the end of 8 weeks, the mortality, and the feed consumption per chick. Table 4 gives the analyses of a composite sample of the droppings from each lot, composed of approximately equal quantities obtained weekly from each lot. At the end of the experiment, the droppings were thoroly mixed, dried in an electric oven for 24 hours, and analyses determined on the water-free material.

Table 4. Analyses of a composite sample of the moisture-free droppings from each lot. Percent.

Lot No.	Protein	Fat	Fiber	Nitrogen-free extract	Ash	Calcium	Phosphorus
1	28.7	3.1	13.0	40.1	15.1	1.5	1.7
2	23.3	3.6	18.2	38.0	16.9	2.7	1.3
3	26.1	3.0	17.3	42.3	11.3	2.1	1.4
4	25.4	3.9	16.9	42.0	11.8	1.6	1.0
5	24.7	3.3	20.0	38.6	13.4	2.3	1.2
6	25.6	3.6	20.6	38.6	11.6	2.1	1.2
7	24.2	3.4	16.6	35.8	20.0	2.6	1.0
8	26.1	3.2	16.9	36.7	17.1	2.4	1.0
9	22.8	3.2	18.1	44.8	11.1	1.7	.9
10	23.5	4.0	20.0	41.0	11.5	1.8	1.0
11	25.5	4.0	18.4	35.3	13.2	1.8	.9

For the sake of clarity, the first four lots will be discussed as a group. From the table it will be seen that there were practically no

differences in the rates of growth of the chicks, mortality, or quantity of feed consumed by the chicks in these lots during the experiment. This shows that the four mashes have the same biologic value and that leaf meals of Korean lespedeza, alfalfa and lespedeza sericea, plus corn starch, can replace mixed wheat feed in an all-mash chick ration when the quantities of protein in each are the same. It also shows that the biological values of the proteins in the three leaf meals were apparently the same.

In lots 6, 8, and 10, where the leaf meals replaced mixed wheat feed, dried skimmilk and part of the ground corn, except in lot 6 which had the full quantity, the rates of growth of the chicks were approximately the same but considerably less than those of the other lots. It will be seen also in lots 5, 7, 9, and 11, where the leaf meals replaced mixed wheat feed, meat scrap and part of the ground corn, that the rates of growth of the chicks were approximately the same but less than those in the control lot which contained the meat scrap. This indicates that the biological value of the proteins in alfalfa leaf meal and the other two leaf meals are inferior to that of the proteins of dried skimmilk or meat scrap.

The analyses of the droppings from the various lots did not differ much, except in the percentage of fiber. This shows that the digestion and excretion of the chicks were approximately the same inasmuch as the analyses of the feeds were practically the same except as to percentage of fiber.

In briefly summing this experiment, it seems that the leaf meals of Korean lespedeza, alfalfa, and lespedeza sericea, with a suitable quantity of starch, can replace mixed wheat feed, on a basis of equal quantities of protein, in the feed of growing chicks but that these leaf meals cannot replace wheat feed and either dried skimmilk or meat scrap, on a basis of equal quantities of protein. The results further indicate that the biological value of dried skimmilk is superior to that of meat scrap on the basis of equal quantity of protein, as shown by the fact that better growth was obtained when these legume leaf meals replaced meat scrap than when they replaced dried skimmilk.

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